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Development of the Simple Economic Model (SEM) for stormwater management



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“The question is not whether stormwater management system maintenance is necessary in a community. Rather, the question is how a community's maintenance programs will be budgeted, staffed, and administered, and who has responsibility for managing inspections, scheduling periodic required maintenance, and funding remedial work. (Haubner et al. 2001)”

“Don't let anyone look down on you because you are young, but set an example for the believers in speech, in life, in love, in faith and in purity” 1 Tim 4 vs. 12

“No company would stay in business long if its management did not know how much product was being produced, how much it cost to produce it, or the market price for the product. ...Why should we treat our natural capital – capital that sustains life on the planet – any differently?” (Olewiler, 2004)

Declaration

This dissertation is prepared for Associate Professor Neil Armitage in partial fulfilment of the requirements for the degree of *Masters in Engineering in Civil Engineering*; as described in the Engineering and Built Environment Student Handbook (2011). This dissertation is a product of the Civil Engineering Department at the University of Cape Town (UCT).

I, Lloyd Norman Fisher-Jeffes, know the meaning of plagiarism and declare that all the work in this dissertation, barring that which I have properly acknowledged, is my own.

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29 / 11 / 2011

Abstract

Sustainable urban Drainage Systems (SuDS) are increasingly being implemented around the world. A common barrier to the wider use of SuDS in South Africa is the uncertainty regarding their total cost. The need for reasonable predictions of life cycle cost is vital, both in terms of ensuring the viability of the proposed projects as well as to allow for comparison with more conventional designs that have historically relied on concrete pipes and culverts to transport the stormwater to nearby receiving water bodies as quickly and efficiently as possible.

Life Cycle Cost (LCC) analysis is commonly used to compare the costs of SuDS with conventional approaches. Few analyses, however, consider all the costs and benefits associated with different approaches. Conducting a LCC comparison without considering the more significant costs can lead to incorrect conclusions, as for example the cost of the pollution associated with conventional systems being externalized onto the environment and not taken into consideration. In conventional systems, highly polluted runoff is often discharged into the receiving water bodies at much higher rates and volumes than prior to development. The levels of pollution and increased rates of runoff over time lead to its degradation. Part of the benefit of utilizing SuDS is the improved water quality, quantity management and groundwater recharge that is achieved through a treatment train that ensures that the runoff discharged into a receiving water body has mitigated impact on the ecosystem. Standard LCC methods seldom take this fully into consideration. This thesis presents a simple economic model (SEM), supported by a macro-enabled Excel model, that attempts to address this weakness and ensure future analyses will be 'fair'.

For the SEM to be useful, costs and benefits need to be considered in a manner that can easily be applied and utilized by all interested parties, be they developers, individuals or local authorities – to this end a SuDS 'Cost Treatment Train', that displays the costs in relation to the party responsible for their operation and maintenance, has been proposed.

The SEM does not attempt to account for every economic cost and benefit, but rather it attempts to compare the different designs and design philosophies on an equivalent and fair basis. The benefits of SuDS, in terms of quantity and quality, are translated into additional costs that are then attributed to the total cost of the conventional system. These costs are determined using the Substitute Cost Principle, and are calculated based on a scalable end-of-pipe treatment facility. The facility considers quality and quantity management criteria as well as the need for ground water recharge, rainwater storage and reuse.

This thesis demonstrates that it is extremely important to consider the costs of externalizing stormwater pollution onto the environment while dispelling the 'myth' that it is too onerous to consider the value of these ecosystem goods and services, and presents a tool that may be utilized for doing so.

Three examples of the SEM's application have been included which have demonstrated the SEM's functionality and its ability to present results which are accessible to a wide range of stakeholder who may not have the technical 'know how' or understanding to undertake such an analysis.

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Abbreviations

Aus	Australia
BCA	Benefit Cost Analysis
BIOCEDDS	Bio-Ecological Drainage System
BMP	Better Management Practises
BMP	Better Management Practises
CBP	Concrete Block Paving
CCA	Capital Cost Analysis
CBR	California Bearing Ratio
CCT	City of Cape Town
CIDB	Construction Industry Development Board
CoCT	City of Cape Town
CSIR	Council for Scientific and Industrial Research
DAC	Damage Avoidance Cost
DBSA	Development Bank of Southern Africa
DoCGTA	Department of Co-operative Government and Traditional Affairs
DPLG	Department of Provincial and Local Government
DWAF	Department of Water Affairs and Forestry
<i>E.coli</i>	<i>Escherichia Coli</i>
EGS	Environmental Goods & Services
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
EUL	Expected Useful Life
FDUP	Flow Diversion Unit Process
FRP	Fibre Reinforced Pipe
IND	India
InUP	Infiltration Unit Process
LCA	Life Cycle Analysis
LCC	Life Cycle Cost/Costing
LCCA	Life Cycle Cost Analysis
LID	Low Impact Development
MAP	Mean Annual Precipitation
MSMA	Manual Saliran Mesra Alam Malaysia
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NEMA	National Environmental Management Act

NPV	Net Present Value
O&M	Operation and Maintenance
O&M	Operations & Maintenance
PV	Present Value
QCUP	Quantity Control Unit Process
QCv	Quantity Control volume
RCP	Reinforced Concrete Pipe
Rev	Recharge volume
RI	Recurrence Interval
RWHR	Rainwater Harvesting and Reuse
S	Recharge Factor
SA	South Africa
SCS	Soil Conservation Society
SDUP	Sedimentation Unit Process
SEM	Simple Economic Model
SFUP	Sand Filter Unit Process
SLAMM	Source Loading and Management Model
SS	Suspended Solids
SuDS	Sustainable urban Drainage Systems
SWMM	Storm Water Management Model
TP	Total Phosphorous
UPVC	Un-Plasticized polyvinyl chloride
UK	United Kingdom
USA	United States of America
USDA	United States Department of Agriculture
USEPA	United State Environmental Protection Agency
WBM	Water Balance Model
WCED	World Commission on Environment and Development
WLC	Whole Life Cycle
WQv	Water Quality volume
WSUD	Water Sensitive Urban Design
APSSF	Austin Partial Sedimentation Sand Filter

Glossary

Term	Definition
Brown-field	A site which has previously been developed, or altered through development.
Buffer strip	A vegetated area (generally grassed) of sloping land designed to convey stormwater and filter out pollutants.
Contamination	The unnatural/anthropogenic introduction of organisms or chemicals that do not naturally occur in the system.
CPv	Channel Protection Volume, used to describe the storm events where the focus is on managing the volume, and rate of flow in minor channels. This usually requires the detention of runoff onsite. This usually refers to storm events with a RI of less than 2 years
CBP	Concrete Block Paving
CBR	California Bearing Ratio: a test for evaluating the strength of road subgrades and basecourses.
Damage Avoidance Cost (DAC)	The estimated value of the goods and services, in the form of stormwater quality and quantity management, provided by a properly designed SuDS system.
Degradation	The general and progressive lessening of stream or channel profiles, or earth's surface, due to long-term periods of water induced erosion and/or scour.
Design storm	Properties of a selected storm. These include depth, duration, and intensity of the rainfall.
Detention pond	A pond designed to be dry except immediately following a storm when it acts to detain runoff and attenuate the peak flow.
Drainage system	All the components making up the system used to drain stormwater from the source to the receiving water course. This may include SuDS and/or conventional components, or a combination of both.
DWAE	Department of Water and Environmental Affairs (Government department responsible for water affairs post 2009).
DWAF	Department of Water Affairs & Forestry (Government department responsible for water affairs before 2009).
Expected Useful Life (EUL)	The duration which an asset is expected to last, assuming a standard level of maintenance and operating procedure.
Extended detention pond	A detention pond designed for the detention of stormwater for an extended period, usually 24-48 hours to ensure water quality treatment.

Filter strip	See buffer strip.
FRC Pipe	Is a Fibre Reinforced Concrete pipe
Goal Seek	Goal Seek is part of a suite of commands called 'what-if' analysis tools. When the desired result of a formula is known but the input value is unknown the Goal Seek function may be used. The function works by varying the value in a specific cell to solve a function (Microsoft, 2011).
Green roofs	A roof designed to be vegetated. The vegetation acts to manage precipitation through interception, infiltration and detention. There are many different forms of green roofs.
Green-field	A site which has not been previously developed, and remains in a natural state.
Ground Water Table (GW)	The upper most level of the zone of saturation below the Earth's surface, except where this surface is formed by an impermeable body.
Infiltration trench	A trench filled with void forming material (generally granular) designed to collect, detain and infiltrate runoff.
Interception storage	Precipitation intercepted by and stored on vegetation, leaf litter etc.
Lag time	The time from the centroid of the excess rainfall to the peak of the runoff hydrograph.
LID	Low Impact Development: an approach to development working with natural processes to manage and treat stormwater as close to source as possible.
Macro	A macro is a series of programmed commands and functions that are stored in a Microsoft Visual Basic. The commands and functions may be executed to perform a specific task (Microsoft, 2011).
Permeable pavement	A general term used to describe a pervious surface designed to allow runoff to permeate through and into pavements subgrade.
Quantity Control Volume (WQ _v)	The volume of runoff which needs to be managed from a quantity control perspective.
Rain water harvesting and re use	Is the capturing and reuse of runoff. Generally collected from roofs in the form of rainwater tanks, but may also be collected in the subgrade of permeable pavement or green roof.
Receiving waters	Natural or man-made systems which receive stormwater runoff.
Recurrence Interval (RI)	The average interval between events exceeding level. The recurrence interval is usually expressed in years.
Retention Pond	A pond with a permanent pool of water. It has the advantage of limited biological treatment not offered by detention ponds. May be

	differentiated from Wetlands by the percentage of vegetative cover. Retention ponds generally have less than 50% of the surface covered.
RS Means	A annual publication in the USA of unit cost prices for construction
Soakaway	A subsurface structure designed to detain and infiltrate runoff into the ground A soakaway in some countries is considered to be a subsurface infiltration trench.
SuDS	Sustainable urban Drainage System, a sequence of structural and non-structural controls which are designed to manage stormwater quality and quantity while enhancing the environmental and aesthetic aspects of a development.
SuDS option	A single SuDS technology e.g. a swale, being considered in isolation of its treatment train.
Swale	A shallow vegetated channel designed to convey runoff. It is generally vegetated with grass which acts to filter the runoff. Swales may be designed to: aid in infiltration (Enhanced Swales); in detention (Check dams); and for biological treatment (Wet Swales).
Time of concentration	Time for precipitation to flow from the most remote point of the catchment to the point of analysis.
Treatment train	A combination of individual unit processes, which together result in treatment. Within SuDS this comprises structural and non-structural controls.
Water Quality Volume (WQ _v)	The volume of runoff which requires water quality treatment in order to reduce/remove pollutants.
Watercourse	A river, stream, channel, canal. It may be a natural or man-made structure in which water flows regularly or intermittently including any associated storage and/or stormwater attenuation dams, natural vleis or wetland areas.
Wetland	A permanent water body. It has the advantage of biological treatment not offered by detention ponds, and longer retention times than retention ponds. May be differentiated from retention ponds by the percentage of vegetative cover. Retention ponds generally have more than 50% of the surface covered.
Whole Life Cost	An estimate of the present day value of all costs of an asset over its expected useful life.
WSUD	Water Sensitive Urban Design: a planning and design approach which considers the whole urban water cycle. It has evolved from being predominantly focused on stormwater to consider all aspects of the urban water cycle.

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University of Cape Town

1. Introduction

Sustainable urban Drainage Systems (SuDS) are currently being introduced to South Africa. A barrier to the wider use of SuDS in South Africa is the uncertainty regarding the total cost. Realistic predictions of life cycle costs is vital, both to ensure the economic sustainability of proposed projects as well as to allow for comparison with more conventional designs that rely on concrete pipes to convey the stormwater to nearby receiving water bodies as efficiently as possible.

Life Cycle Cost Analysis (LCCA) may be used to compare the costs of SuDS with conventional systems. Failure to quantify the environmental costs and benefits associated with the two approaches however results in two very different systems being compared using a set of criteria advantageously weighted towards conventional designs. Incorrect conclusions will be reached if a LCCA is conducted without considering the significant costs that are externalized onto the environment by conventional systems. A significant benefit of SuDS is the improved water quality, quantity management and the groundwater recharge that is achieved through the treatment train that ensures that the impact of runoff discharged into a receiving water body has been adequately mitigated. Standard LCCA's seldom take this into consideration. A review of available models/tools for undertaking economic analyses showed that none were appropriate in their entirety for the South African context.

The Simple Economic Model (SEM) attempts to compare different stormwater management designs on an 'equivalent and fair basis' and was developed to address the shortcomings of the LCCA approach. The quantity and the quality benefits of SuDS are translated into additional costs that are attributed to the total cost of conventional systems in the form of the 'Damage Avoidance Costs (DAC)'. The SEM allows informed decisions regarding alternative designs for stormwater management to be made in an 'equivalent and fair manner'.

This document is structured to provide sufficient literature and motivation for the acceptance of the SEM. **Chapter 2** is a review of relevant literature. It provides the context in which the SEM was developed. The literature review considers a number of topics including, civil engineering, economics, environmental science and law. **Chapter 3** describes the method that was followed in this thesis resulting in the development of the SEM. **Chapter 4** presents an overview of the development of the SEM highlighting the fundamental equations and procedures, while also motivating any assumptions that have been made. **Chapter 5** demonstrates the application of the SEM to three case studies of different scale with different site characteristics. **Chapter 6** concludes this document by comparing the goals of the SEM with its capabilities. **Chapter 7** highlights a number of potential areas that require further research.

A number of important appendices have been included. The appendices include: designs of the Mitchells Plain District hospital; the macro-enabled Excel model; a user guide for the Excel model; and general user guidelines for the SEM including fact sheets that enable the user in South Africa to fully utilise the SEM.

2. Literature Review

2.1 Introduction to literature review

This study requires an understanding of a number of disciplines including civil engineering, economics, and environmental science. The literature review is structured in order to provide the reader with the requisite knowledge to understand each section by drawing on the information from previous sections.

Section 2.2 discusses the key concepts, and fundamental areas of knowledge required to understand the following sections. **Section 2.3** discusses the different types of drainage infrastructure and how the design approach may impact on the economics of the system. **Section 2.4** discusses the important concept of environmental goods and services; what environmental goods and services are provided or impacted by the different approaches to stormwater design; and how these may be evaluated. **Section 2.5** considers the different approaches that may be used in evaluating the economics of stormwater infrastructure. **Section 2.6** highlights international studies comparing SuDS and conventional systems, and highlights the deficiencies in these studies. **Section 2.7** discusses the local economic factors that need to be accounted for in any analysis undertaken in South Africa. **Section 2.8** highlights the legislative context with respect to stormwater management in South Africa. This important section motivates for better stormwater management. **Section 2.9** reviews a number of the tools available for evaluating economics of stormwater systems, and identifies the advantages and disadvantages of these tools. **Section 2.10** concludes the literature review.

Each section ends with a summary titled “What is required in a South African model?” that indicates the key points that should be included or considered in any model for considering the economics of urban stormwater drainage in South Africa.

2.2 Key concepts

A series of workshops around South Africa in 2011 highlighted an apparent reluctance of South African engineers and practitioners to consider ecosystem goods and services. Civil engineering consultants in South Africa argue that it is too impractical, too expensive and economically unviable to treat stormwater. Preliminary research has indicated that this may be true were the systems to be retrofitted. In South Africa, a small proportion (10%) of the population finances the burden of paying for such infrastructure through direct taxation (Futuse, 2007). At a time when South Africans are struggling to pay increased rates for electricity, potable water, sanitation and solid waste disposal fees, implementing the changes required could result in increases in local government rates in the order of 30% (Fisher-Jeffes, 2009). Dealing with stormwater, and water pollution in general, is but one of many challenges facing cities across South Africa. Nascimento *et al.*, 2005 have shown that if systems are designed not to externalize the costs onto the environment at large, it will likely be significantly more economical. Nascimento *et al.*, 2005 also indicate the cost of the

system, when reduced to cost per capita, was dependent on the density of development. The higher the density the lower the cost.

Developing countries, South Africa being one, are rapidly urbanizing. Human demands continue to place greater demands on natural resources, effectively resulting in the degradation of our ecosystems (Crane, 2010). Ecosystems supply society with a vast number goods and services, and the more degraded a system, resulting from anthropogenic abuse, the less these systems can supply. Crane (2010) suggest that in order to “*eradicate poverty; growing consumption must be decoupled from rising levels of natural resource use.*”

Stormwater affects society in a range of manners. It has social, political, economic and environmental implications. Stormwater management therefore requires an interdisciplinary approach. This study intends to cover the key aspects that have economic implications for the management of stormwater systems. Section 2.2 provides an overview of the goals of stormwater management, as well as the background information essential to understanding the philosophy underlying SuDS. It discusses how different factors impact on the economics of stormwater management, and how economic comparisons of the system should be undertaken.

2.2.1 Goals of stormwater management

“*Stormwater is precipitation that travels along the surface, and to a lesser extent subsurface, as runoff* (Graham, 2003).” The purpose of stormwater management is to “*protect the health, welfare and safety of the public, and to protect property from flood* (CSIR, 2000)” by managing floods.

The conventional sewer approach and Sustainable Drainage Systems (SuDS) are the two commonly implemented approaches to urban stormwater management. SuDS are gradually replacing the conventional approach as the standard internationally. Stormwater management has evolved from initially managing stormwater from a risk perspective by using a ditches, pipes and stormwater pipes. Stormwater management is increasingly considering all aspects of sustainability including social, environmental, economic etc. (Debo & Reese, 2003). It is important to consider what the goals of the system are and how it interacts and affects other systems and sectors.

The ‘Red Book’ (CSIR, 2000) states that the goals of stormwater management are:

- *“The need to protect the health, welfare and safety of the public, and to protect property from flood hazards by safely routing and discharging stormwater from developments;*
- *The quest to improve the quality of life of affected communities;*
- *The opportunity to conserve water and make it available to the public for beneficial uses; the responsibility to preserve the natural environment;*
- *The need to strive for a sustainable environment while pursuing economic development; and*

- *The desire to provide the optimum methods of controlling runoff in such a way that the main beneficiaries pay in accordance with their potential benefits.”*

The ‘Red Book’ (CSIR, 2000) could be accused of being out-dated due to the design approach – of using piped networks – it promotes. While this may be true with design, the goals listed above are in line with the goals of SuDS and not with conventional systems. However the authors seem not to have been aware of the means of achieving these principles.

2.2.2 SuDS: ‘a new paradigm’

“*SuDS attempts to mimic the pre-development situation*” (Armitage, 2010) and is based on the three principles of managing quantity, quality and amenity (Woods Ballard *et al.*, 2007; Jefferies, 2010). The SuDS Triangle (Figure 2-1) identifies appropriate solutions as anything within the zone where all three principles are met. This is accomplished by managing runoff using the treatment train shown in Figure 2-2.

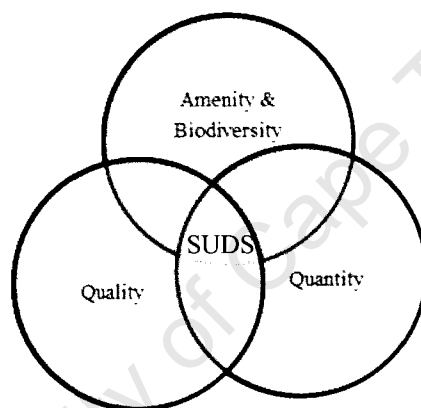


Figure 2-1 : SuDS Triangle (Woods-Ballard *et al.*, 2007)

The treatment train comprises a range of integrated components managing runoff at different scales (Jefferies, 2010):

- Good housekeeping: education and pollution prevention programs to reduce sources of pollution and runoff;
- Source control: control of runoff close to where the rain falls;
- Local control: attenuation and treatment for a group of buildings; and
- Regional control: a number of sites.

A range of SuDS technologies/components may be used in the treatment train as shown in Figure 2-2. The successive linking of each of these technologies results in the formation of a treatment train.

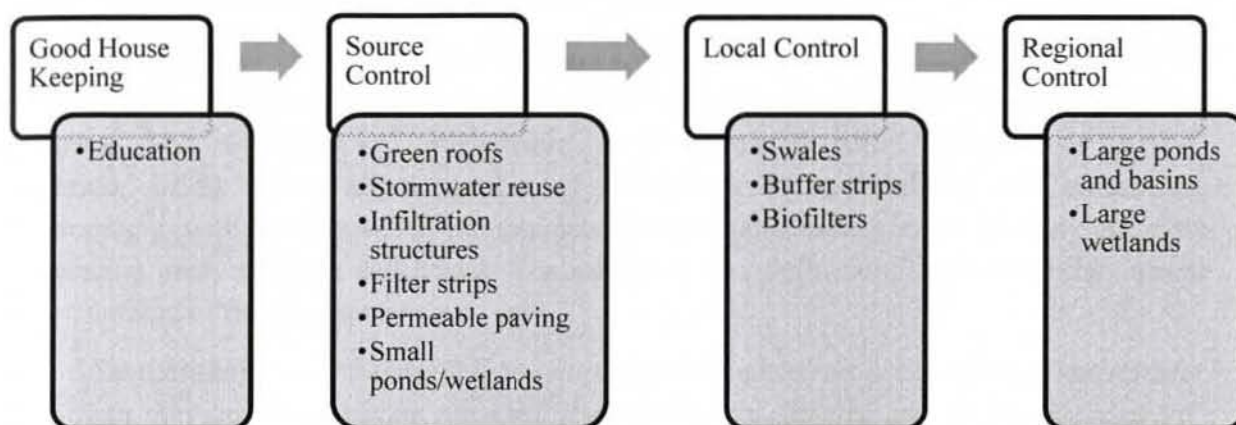


Figure 2-2 : Typical SuDS technologies in Treatment train (Armitage, 2010; Jefferies, 2005; Woods-Ballard et al., 2007)

The difference between conventional and SuDS design is significant. Where conventional design simply focuses on quantity management (Parkinson *et al.*, 2007), SuDS consider all aspects i.e. quantity, quality and amenity (Woods Ballard *et al.*, 2007). The aim is to engineer developments rather than the environment as shown in Figure 2-3. The focus SuDS have on quantity, quality and amenity has amongst others the following benefits:

- *“Reduced flooding*
- *Improved water quality*
- *Increased ground water recharge*
- *Reduced infrastructural expenditure*
- *Enhanced aesthetics & property values*
- *Reduced energy consumption”* (USEPA, 2000).

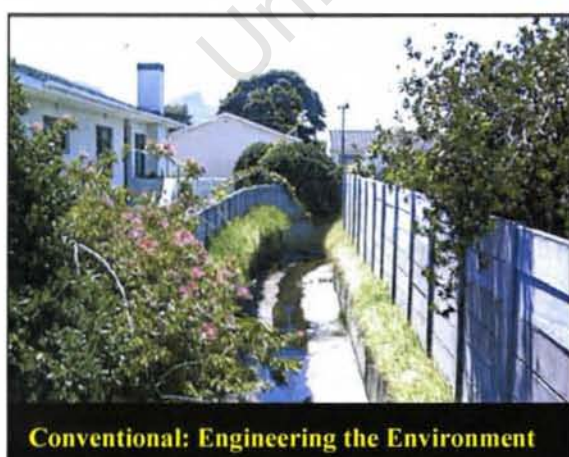


Figure 2-3: Conventional vs. SuDS (Wood, 2010)

2.2.3 ‘Sustainability’ vs. ‘Sustainable Development’

“Sustainability” and “sustainable development” are currently used terms. Understanding this terminology is vital as it is increasingly included in policy at all levels of government and business. The definition of sustainable development is still “*dangerously vague*” (Mebratu, 1998). There are a number of definitions of sustainability and sustainable development, with a bias towards the interests of the organization from which they originate influencing many of these definitions. The following two definitions summarize the current understanding of the concepts:

- i) **“Sustainability** ... *is based on the recognition that when resources are consumed faster than they are produced or renewed, the resource is depleted and eventually used up*” (Ecological Footprint, 2007)
- ii) **Sustainable Development** is “... *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (WCED, 1987)

In summary, sustainability is the recognition and the consideration of the absorptive and regenerative capacities of a system while sustainable development is development accomplished within these limits.

2.2.4 Economics – “the need to consider more than money”

“No company would stay in business long if its management did not know how much product was being produced, how much it cost to produce it, or the market price for the product. ...Why should we treat our natural capital – capital that sustains life on the planet – any differently?” (Olewiler, 2004)

The point that Olewiler (2004) is making, is that it is no longer possible nor logical to only consider one form of capital (monetary/manufactured) to the detriment of other forms of capital. The different forms of capital, as discussed in Goodland & Daly (1996) are highlighted in Table 2-1.

It is also worth noting that just as money may gather interest thereby increasing in value, so may other forms of capital as shown in Table 2-1. This may occur through the ecosystem goods and services offered by natural capital (de Wit *et al.*, 2009) or the advances resulting from education that forms part of the social capital. It is vital that the cumulative capital accounts (manufactured, social and natural) be kept in balance. Where one is depleted, investment should be made into another. This is not generally the case as is evident in Figure 2-4, which shows “*the change in net national savings in 2001 for countries in which there was a decline of at least 5% in net national savings due to the incorporation of resource depletion or damage from carbon emissions.* (Millenium Ecosystem Assessment, 2005)”. Many countries are rapidly depleting different forms of capital and are effectively becoming ‘poorer’.

Table 2-1: Forms of Capital (Based on Goodland & Daly, 1996)

Type of capital	Description
Natural	Natural Capital is essentially the natural unaltered environment, and is defined as the stock of environmentally provided assets, from which goods and services are derived.
Social (including Human)	Social Capital includes people, their capacities, and their education. The institutions governing society.
Manufactured	Manufactured Capital is the goods created by society and includes items such as houses, roads and factories

South Africa is listed as one of the countries depleting its resources at a relatively slow rate yet managing to increase its wealth. The Millenium Ecosystem Assessment (2005) report states that the estimates of net national savings is an overestimate as *“it does not include potential changes in many ecosystem services including depletion of fisheries, atmospheric pollution, degradation of sources of fresh water, and loss of non-commercial forests and the ecosystem services they provide.”* This suggests that South Africa may not in fact be increasing its wealth. It is vital that future development at least considers the impacts on all forms of capital.

2.2.5 What is required in a model for South Africa?

The model must:

- Recognise that stormwater systems are designed with different goals in mind;
- Allow for systems designed with different primary goals to be considered; and
- Account for the impacts on different forms of capital.

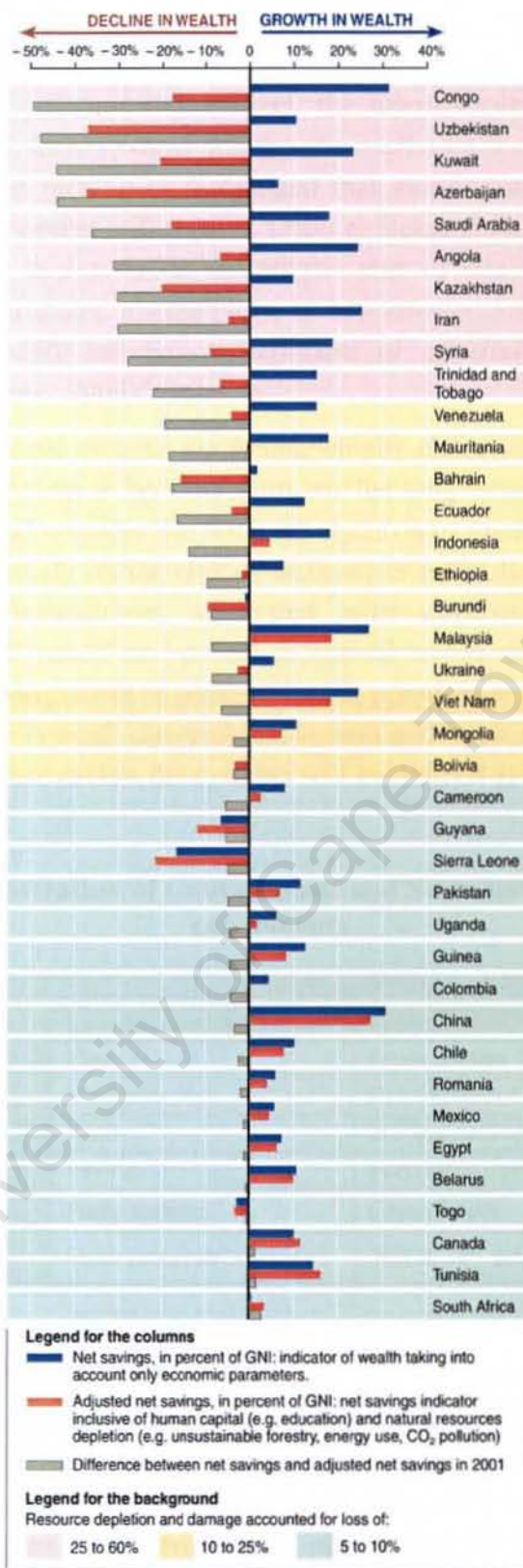


Figure 2-4: Net National Savings in 2001 Adjusted for Investments in Human Capital, Natural Resource Depletion, and Damage Caused by Pollution Compared with Standard Net National Savings Measurements (Millennium Ecosystem Assessment, 2005)

2.3 Drainage infrastructure valuation

The requirements of the different stakeholders, the interdisciplinary nature of the design team, the available capital, local by-laws and the site itself all affect the cost of implementing a stormwater management plan. It is recognized that stormwater is but one of the many services that a new development will require. Debo & Reese (2003), emphasize the need for stormwater infrastructure design to be an integral part of site design. It may affect the placement of other infrastructure, alternatively, if “*stormwater considerations are tacked on at the end, it will probably not be cost effective or effective in reducing impacts of development.* (Debo & Reese, 2003)”

SuDS and Conventional systems are fundamentally different, as noted above; this will influence the cost of the system in both the short and the long term. This section will develop on the previous section and consider the different stormwater management strategies and the associated costs. In their study on the cost of stormwater controls, Narayanan & Pitt (2008) consider a variety of technologies associated with stormwater. These included the management of ‘standard’ runoff and runoff in critical source areas. While important and relevant to stormwater management in general, for the purposes of this study it was necessary to narrow the focus to the ‘typical’ conventional system and ‘typical’ SuDS technologies. For the purposes of this literature review the systems will be defined as shown in Table 2-2.

Table 2-2: Categorization of Conventional and Sustainable drainage systems components

Component / Technology	Drainage System	
	Conventional System	SuDS
Pipes		Grass Swales
Manholes		Bio filtration
Inlets		Infiltration trenches
Paving		Permeable Pavements
Pump stations		Green Roofs
Open (concrete) Channels		Wet & Dry detention ponds

2.3.1 Conventional systems

In their studies on the cost of stormwater management Heaney *et al.* (2002) and Narayanan *et al.* (2008) have extensively reviewed the techniques for estimating the costs of conventional stormwater systems, especially in the area of estimating the costs of pipes. Both reports identify the same techniques. This review does not discuss the literature covered in these documents, which are already fairly similar and detailed, rather it highlights the range of techniques available and what these and other authors have used and identified as appropriate.

Conventional systems are associated with a wide variety of costs: excavation, bedding, pipe size and material, backfill type and delivery costs, inlets and catch pit costs and manhole

costs (Narayanan & Pitt, 2008). This section will highlight how these costs form part of the models, tools, and techniques used to estimate the costs of stormwater drainage.

Similarities between wastewater and stormwater systems allow for comparisons of the techniques for estimating the cost of pipelines for a catchment. Table 2-3 indicates the complexity of the formulae used and the huge assumptions made in grappling with trying to reduce a complicated design into a simple formula. Not one of these formulae uses South African data. The majority of these equations emanate from research conducted between 30 to 40 years ago. While construction cost indices may be used to update the results from these formulae, due to their age and the changing catchment characteristics, including increased urbanization and densification, the results would be questionable. There are however other approaches that may be taken.

Table 2-3: Overview of pipeline cost estimate 'tools' (from Heaney *et al.*, 2002 & Narayanan *et al.*, 2008)

Source	Developed by/using	Equation
Knapp, 1967	Presented 2 models for the investment costs of data collected from 'typical' stormwater drainage systems	7 Variables
Dajani <i>et al.</i> , 1971	Regression analysis using actual construction bids data	6 Variables
Rawls <i>et al.</i> , 1972	Examined 126 small urban drainage systems and presented a nonlinear relationship for predicting costs.	6 Variables
Grigg & O'Hearn, 1976	Developed an estimate of pipeline costs as a function of the selected diameter, return period and 'urbanisation factor'	5 Variables
Tyteca, 1976	Developed a wastewater conveyance system cost	6 Variables
US Army Corp of Engineers, 1979	Cost of gravity pipes for MAPS Software, to aid in estimating water infrastructure costs	12 variables
Han, Rao & Houck, 1980	Estimated the costs of stormwater drainage as part of a system optimization model	3 formulae
Moss & Jankiewicz, 1982	Promoted the use of LCC in the selection of stormwater infrastructure	Present worth of cost method
RS Means	An annual USA Publication providing unit costs for building components	Unit cost data

Bester *et al.*, (2010) present a set of simple to apply algorithms including all components involved in the construction of a gravity pipeline. The cost of manholes, for example, is averaged over the length of the pipeline. The study effectively averaged the values of many successful tenders for South Africa. These formulae are useful and will give an indication of an average cost for constructing a gravity sewer system (Bester, 2010). They do not account for local factors and this should be noted when they are applied. The formulae do not consider aspects such as kerbs, catch pits and connections into the trunk line. These important aspects should be accounted for in any design.

The potential inaccuracies highlighted above, both in the formulae development and age, could be the reason why (Narayanan & Pitt, 2008) chose to develop their own Excel based costing model for conventional systems making use of RS Means data (annually published construction cost data in the US by Reeds Construction). This method considers the costs of trench excavation, bedding and backfilling. It then sums them as a cost per unit, then cost per pipeline and finally total project cost.

A number of cost estimate equations have been developed for individual components such as manholes, inlets, curbs and gutters (Narayanan & Pitt, 2008; Heaney *et al.*, 2002). The most accurate method would likely be the use of RS Means for the reasons discussed above. With respect to open channels Heaney *et al.* (2002) suggest estimating the cost on an individual case basis. U.S. Army Corps of Engineers (1979) MAPS Software provide a template for doing these calculations (Heaney *et al.*, 2002). Narayanan *et al.* (2008) reference a number of USEPA studies that could be used to estimate the costs using the Analogy cost estimate method.

The literature review failed to identify any sources that supplied reliable data on how to estimate the O&M costs associated with conventional systems. It was evident that studies, such as Narayan & Pitt (2008) made estimates based on experience of the maintenance burden of conventional systems as no reference to how the maintenance costs were estimated was made. One local source of data was identified. The South African 'Guidelines for Infrastructure Management' (DPLG, 2006) is shown in Table 2-4. The values presented appear to be unreliable when compared to typical rates and maintenance frequencies. An in-house study by the City of Cape Town further suggested that their stormwater budget for maintenance and operations was approximately a tenth of what was required (Austin, 2010). It is important to note that while these figures are presented in the 'Guidelines for Infrastructure Management' (DPLG, 2006), there is no reference to where these figures may have come from and thus it is difficult to ascertain how appropriate they are. The figures should be used circumspectly; alternatively local data should be used where it is available.

Table 2-4: Conventional Systems O&M (DPLG, 2006)

Asset	Operations (% CRC*)	Maintenance (% CRC*)
Open Channels –Lined	0	1.4
Open Channels – Unlined	0	10
Pipes (<600 mm Diameter)	0	0.65
Pipes (>600 mm Diameter)	0	0.35
Nodes and Transitions	0	1
Erosion Protections	0	1.25
Ponds	0	0.35
Pump station Mechanical plant	2	4.6
Pump station Electrical plant	3	2.3
Pump station Civil plant	0.1	0.5

*CRC: Capital Replacement Cost

The different components of a conventional stormwater system generally have no agreed upon Expected Useful Life (EUL). Few municipal asset management plans will define the EUL, and where they do, the EUL's vary dramatically or are questionable. This is especially evident in South Africa where available Municipal Asset Management Plans will estimate the EUL of a concrete pipe to be 40 years. There is a surprising lack of consistent international literature on the EUL of conventional systems. A set of EUL's (Table 2-5.) taken from a recent study in South Australia by Tonkin Engineering Science, is presented below. The study looked at the current Asset Management strategies of a number of municipalities and the results relating to stormwater are presented. The numbers in the sample column represent the number of local authorities that contributed data. It is worth noting that where assets are not actively managed, their EUL may deteriorate far sooner than expected (Narayanan & Pitt, 2008). The study conducted by Ellis & Callaghan, (2009) showed the EUL used by different institutions could vary by up to 50 years!

Table 2-5: EUL of Stormwater network components (Ellis & Callaghan, 2009)

Asset	Sample (councils)	Minimum (years)	Maximum (years)	Median (years)
RCP	8	50	100	100
FRC Pipe	4	80	100	100
Box Culvert	6	50	100	75
Side Entry Pit	4	50	80	55
Junction Box	4	50	80	55
Headwall	5	50	80	50
Lined Channel	4	50	100	80
Unlined Channel	4	10	100	100

2.3.2 SuDS

While there are a number of SuDS technologies, this research will focus only on those that are included in the proposed, South African SuDS Guidelines. It is important to understand the SuDS Management approach, and the impacts of technology selection on the costs and benefits of the design. SuDS aim to take advantage of a treatment train making use of source, local and regional controls. Figure 2-2 gives an overview of where the different technologies fit into this continuum.

SuDS are fundamentally different to conventional systems and therefore the factors that influence their costs, both capital and operating are different. This section highlights how the principles of SuDS and design decisions influence the costs of a SuDS system.

Unlike conventional piped systems, SuDS are not solely a risk management solution. Quantity, quality and amenity all need to be considered and it is therefore important to recognize that the total costs for any drainage system should reflect everything required to keep the system operating. The effectiveness of a SuDS system is based on the use of a treatment train where each successive unit process further treats the runoff. 'Good

housekeeping', is especially important in order to minimize regular maintenance such as litter collection.

The design of the treatment train may result in different outcomes, especially with respect to cost. This is best demonstrated using an example from Berwick (2011). The three treatment trains shown in Figure 2-5 could all potentially meet the short term local pollutant removal criteria for a hypothetical catchment. It may therefore seem logical to use treatment train 1, to contain costs. However:

- i) In Treatment Train 1, all the runoff with associated pollutants is piped directly into the wetland. This implies that all the suspended solids will collect in the wetland and will require frequent removal.
- ii) In Treatment Train 2, the swales convey the runoff to the wetland. During this process the swales will filter the runoff and remove a large portion of the sediment, lessening the quantity entering the wetland.
- iii) In Treatment Train 3, a dry detention pond further detains the runoff before releasing it to the wetland. This allows almost all the sediment to settle out and prevents sediment from entering the wetland.

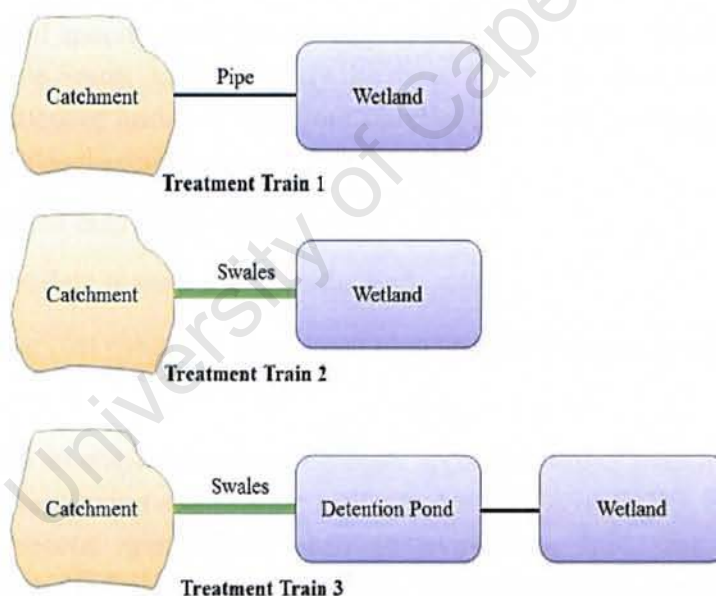


Figure 2-5: Three treatment trains (adapted from Berwick, 2011)

Treatment Train 1 may well have the lowest capital cost, but as it is generally more cost effective to remove sediments from dry above ground SuDS (Berwick, 2011), both Treatment Trains 2 and 3 are likely to prove to be more cost effective in the long term. It may be argued that Treatment Train 3 is over-designed. This would however depend on the catchment, pollutant load and the receiving water body. It is therefore vital that the long term functioning

of the SuDS technology and treatment train is considered as an integral part of the design and costing process.

The bulk of expenditure on SuDS is related to earthworks and landscaping. Estimating accurate unit rates is difficult, especially within the landscaping profession. Additionally, the following aspects, *inter alia*, of a development will influence the costs of the system:

- “Project scale and unit costs
- *Retrofits vs. green fields*
- *Regulatory requirements*
- *Public vs. private design and construction*
- *Contractor vs. public works crew*
- *Flexibility in site selection, site suitability*
- *Partnerships*
- *Levels of experience with the technologies, by both designers and contractors” (Lampe et al., 2005).*

The last point is of specific relevance in any country where the ‘SuDS approach’ is relatively new – for example South Africa. Clearly these factors are determined by both the site and the regional influences and it is therefore unreliable to use “averages” for estimating costs. Lampe *et al.*, (2005) therefore suggest that:

- Available cost data is very uneven;
- Capital cost data is very site-specific; and
- Engineering cost estimates are a good planning-level measure of capital costs.

It is better to take an engineering cost estimate approach, rather than making use of equations developed from regression analysis for estimating the LCC of SuDS. Firstly, this would be in line with the recent approaches taken in evaluating LCC for conventional systems (Narayanan & Pitt, 2008; Heaney *et al.*, 2002). Secondly, there have been no cost studies into SuDS in South Africa. Thirdly, many of the SuDS are “*comprised of well-known construction materials and techniques*” (Lampe *et al.*, 2005).

Many SuDS options make use of vegetation e.g. swales, wetlands and green roofs. These SuDS options at first require irrigation and replanting until the vegetation is fully established and these costs should be included in the capital costs. Accurately determining these costs may be difficult and the South East Queensland WSUD (Moreton Bay Waterways and Catchments Partnership *et al.*, 2006) guidelines state that: “*It is important to note that swale systems, like most WSUD elements that employ vegetation based treatment processes, require approximately two growing seasons (i.e. two years) before the vegetation in the*

systems has reached its design condition (i.e. height and density). In the context of a large development site and associated construction and building works, delivering swales and establishing vegetation can be a challenging task". For this reason, it is suggested that a phased approach to construction be undertaken, whereby drainage is implemented first, then protected and established throughout the rest of the construction process (Moreton Bay Waterways and Catchments Partnership *et al.*, 2006). This is in line with Woods-Ballard *et al.* (2007) and Debo & Reese (2003) who suggest that the areas where SuDS are to be established be protected from the construction process as far as possible to prevent pollution and compaction that limits infiltration. It is important to recognize that a number of factors affect the establishment costs. These include the timing of planting, the watering and the weed control requirements.

The importance of designing a SuDS system as a treatment train is discussed above. Unlike a conventional system, each component (SuDS option) has a range of performance variables. Each of these variables has potential impacts on the costs of implementing the specific SuDS option, as well as on the cost of the future maintenance requirements of the system as a whole. When optimizing the system a range of performance variables and their impacts on maintenance costs need to be considered.

Developers may be concerned that SuDS options may decrease the area that may be developed (Buys & Aldous, 2009; ECONorthwest, 2007). This concern is real, as many SuDS options require a larger land take than conventional options. On the other hand, where SuDS are correctly implemented with consideration of quantity, quality and amenity, the properties could gain additional value (see Section 2.4.5). The potential for gaining additional value will be dependent on the attitude and willingness to adopt these technologies. The sentiments of a Pennsylvania developer should be considered i.e. *"We are required to build urban runoff management basins. Why not take an environmental negative and turn it into a positive, into a visual asset?"* (Tournier & Westmacott, 1992)."

The design process must not simply consider the capital costs but as illustrated with the three treatment trains (Figure 2-5) must fully consider the maintenance requirements. Facilities should be designed to be as maintenance free as possible, and competent designers should *"recognize that all structures require periodic maintenance, inspection and repair* (Debo & Reese, 2003). Designs should allow for the frequency and types of maintenance that the system will require (Berwick, 2011) and the associated cost should be considered as part of the design process.

It is vital that SuDS are maintained to ensure performance i.e. quantity and quality and amenity values are maintained (Berwick, 2011; Haubner *et al.* 2001; Woods-Ballard *et al.*, 2007). *"The question is not whether stormwater management system maintenance is necessary in a community. Rather, the question is how a community's maintenance programs will be budgeted, staffed, and administered, and who has responsibility for managing inspections, scheduling periodic required maintenance, and funding remedial work"* (Haubner *et al.*, 2001). SuDS require constant maintenance to ensure proper functioning. Failure to do so results in premature failure and in the system needing to be overhauled which may have significant cost implications. In the absence of proper maintenance, the condition

of conventional stormwater infrastructure will initially deteriorate slowly – increasing with time. SuDS deteriorate at a more rapid rate. Continued failure to maintain systems will accelerate the system's loss of condition resulting in premature failure. Poor design and failure to maintain SuDS systems results in many SuDS failing prematurely.

All SuDS require regular inspection to ensure that potential problems are identified and dealt with timeously. SuDS require regular/routine maintenance on regular basis to ensure proper functioning (Woods-Ballard *et al.*, 2007; Berwick, 2011; Lampe *et al.*, 2005). This includes the following tasks:

- Litter / debris removal;
- Grass & vegetation management including cutting, pruning, invasive species removal, weeding; and
- Minor sediment removal, erosion management, etc.

Less regular maintenance / irregular maintenance is required to achieve:

- Sediment management;
- Vegetation replacement; and
- Minor overhauls.

Corrective maintenance is required in response to failures in the SuDS integrity e.g. where a swale is eroded. Three different levels of maintenance may be considered as detailed in Table 2-6. When considering what level of maintenance is appropriate, it is important to recognize that amenity is a central SuDS principle and that it requires maintenance as well. In certain circumstances, for example where a detention pond is out of sight and has no amenity value, the lowest level of maintenance would be appropriate i.e. ensuring the detention pond functions from a quantity and quality perspective. Conversely, upmarket, gated communities may emphasize the aesthetic aspects of SuDS and hence a high level of maintenance, focusing on amenity aspects would be important. Generally, the medium level that considers all aspects of SuDS – quality, quantity and amenity – is appropriate (Berwick, 2011).

SuDS treatment trains, unlike conventional systems, are relatively complex when it comes to determining both the system's life cycle and the life cycle costs. Appendix F details estimated maintenance rates and frequencies for the SuDS options. Certain costs, such as the impacts of storms or periods of extreme heat on the cultivation of vegetation are difficult to predict. Extremes of either require extensive replanting. Climate and site-specific considerations need to be addressed by the project team.

Table 2-6: Levels of maintenance for SuDS (after Berwick, 2011)

Maintenance Level	Description
Low	Basic maintenance ensuring functioning (quality & quantity) of the SuDS option
Medium	Intermediate maintenance ensuring functioning (quality & quantity) and reasonable level of amenity
High	High maintenance ensuring both the functioning, and ensure a high amenity level (appearance). Additional maintenance is for amenity value only and does not impact on functioning

A review of the literature showed that there is no generally agreed upon EUL for the different components of a SuDS System. Few studies attempt to estimate the EUL and where they do, the estimated EUL's vary dramatically. This could be related to the poor maintenance and record keeping of SuDS that has occurred in countries where SuDS was first introduced. Poor maintenance results in the systems failing which in turn results in the SuDS option developing a poor reputation. This may be a cause for the lower estimated EUL's. Proper maintenance on the other hand results in many SuDS technologies operating for extended periods, likely resulting in the higher estimated EUL's. Table 6 indicates the variability of the EUL of SuDS.

Table 2-7: EUL of SuDS network components

SuDS option	MUSIC, (2009)	Narayanan, (2008)	Porsche <i>et al.</i> , (2003)	FHWA	EPA	Jefferies, (2005)	Shackel, (2006)
				in Jefferies, (2005)			
Rain Water Harvesting	25 years	>20 years					
Green Roofs		10-40 (based on design)	Up to 90 years				
Infiltration Trenches & Soakaways	20-50 years			10 years	5-15 years		
Bio retention	25-50 years	20 used for LCCA study					
Permeable Paving						15-20 before clogging	>10 years maximum of 25 years
Swale	25-50 years			20-50 years		10 years	
Buffers & Filter Strips	25-50 years	20 used for LCCA				20-50 years	
Wetlands & Retention Ponds	30-50 years			20-50 years	>20 years		
Detention Ponds	50 years				20-50 years	Dependent on maintenance	

Attempting to predict the life cycle costs of a SuDS system is difficult as it is based on the technical design and the level of maintenance. Significant cost is incurred when the SuDS option is overhauled / replaced. This reinforces the importance of the accuracy of the estimated EUL.

Table 2-8, based on experience in UK, gives an overview of the relative costs of different SuDS options. The relevance of Table 2-8 will be dependent on all the factors discussed above.

Table 2-8: Relative costs of different SuDS (Woods-Ballard *et al.*, 2007)

SuDS option	Land Take	Capital	O&M
Rainwater Harvesting	N/A	Low-High	Low-Medium
Soakaways	N/A	Low	Low
Trenches	Low	Low-Medium	Medium
Green Roofs	N/A	Low-High	medium
Bio retention	High	Low	Medium
Grass Swale	High	Low	Medium
Permeable Pavements	Low	Low-Medium	Low
Filter Strips	High	Low	Low
Buffer Strips	High	Low	Low
Dry Stormwater Ponds	Medium	Low	Low
Retention Ponds	High	Medium	Medium
Wetlands	High	High	Medium-Low

2.3.3 What is required in a model for South Africa?

The model needs to account for:

- Whole stormwater drainage systems and single components.
- The complexities of SuDS and conventional systems:
 - The different techniques of evaluating costs; and
 - The model must consider and compare different maintenance scenarios.

2.4 Environmental Goods & Service (EGS)

It is widely recognized that the philosophy underlying SuDS encourages the use of natural processes. SuDS have the potential to supply a number of goods and services to stakeholders. These include, but are not limited to: flood mitigation, improved water quality, increased ground water recharge and improved aesthetics resulting in increasing property values. The following section discusses the natural environmental goods and services that conventional systems degrade, and that the SuDS approach attempts to sustain and reintroduce.

The difference between Natural Assets (NA) and Ecosystem/Environmental Goods and Services (EGS) requires clarification. NA are “the stocks of environmental resources owned by” an individual or institution, whereas EGS “are the flows of benefits derived from these assets (the interest or services generated by the natural capital)” (de Wit et al., 2009).

A SuDS design effectively reinvests in natural capital which results in increased ‘interest’ in the form of EGS. In comparing stormwater systems, the focus is commonly on the costs to stakeholders and not necessarily about the balance sheet or the different forms of capital.

There are a number of ways of understanding the different ecosystem services. The Millenium Ecosystem Assessment (2005) provides a simple representation of the different ecosystem goods and services such as: provisioning, regulating, cultural and supporting goods or services (Figure 2-6). Considering the ecosystems goods and services in these four groups assists in identifying possible valuation techniques, and ensures that a service is not valued more than once when conducting an economic analysis. These considerations are further discussed in Section 2.5.4. Most of the EGS discussed in this section classify as a regulating service as these are most directly associated with stormwater management.

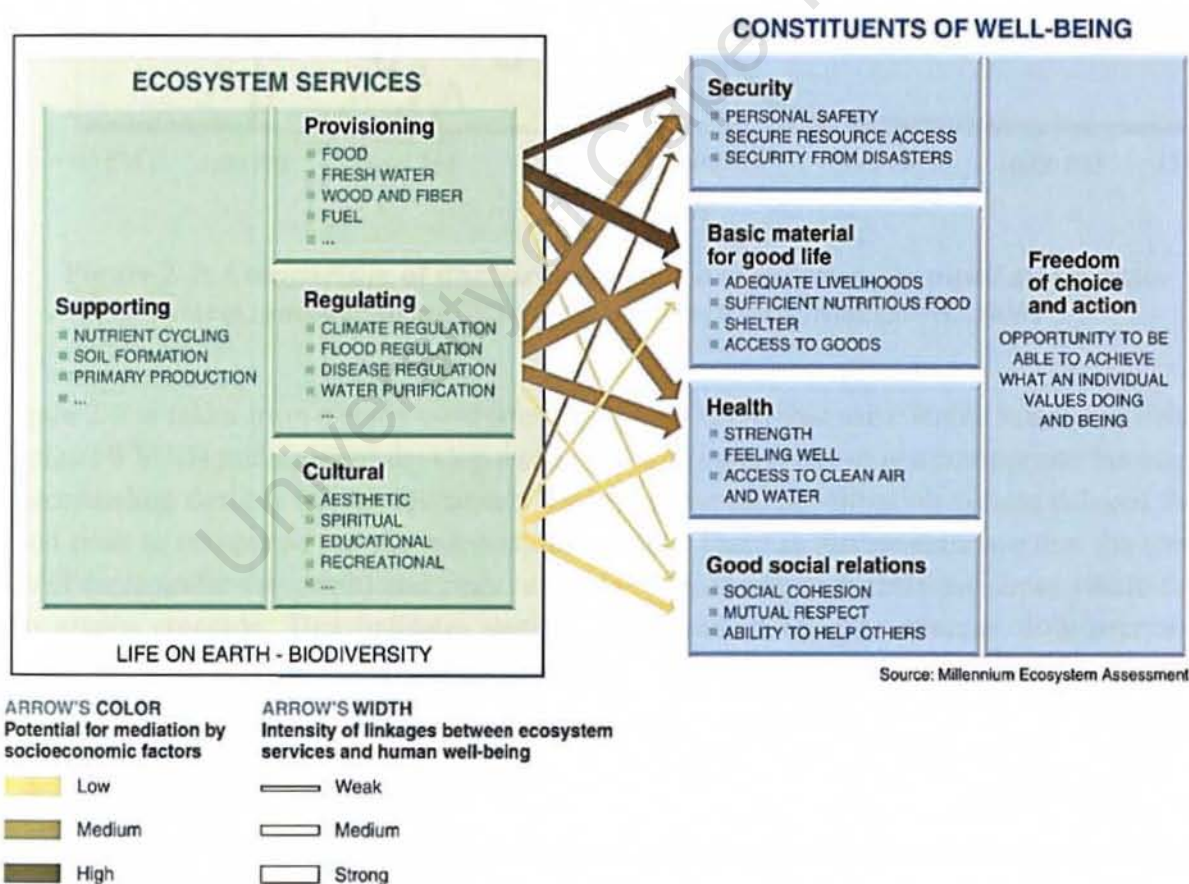


Figure 2-6: Ecosystem Services (Millenium Ecosystem Assessment, 2005)

2.4.1 Reduced flooding

It is widely recognized that increasing urban development is resulting in increased runoff volumes and peak flows. The cumulative effects of these impacts on flood peaks is estimated to range from 20-50% in residential areas and more than 100% in heavily industrialized areas (SANRAL, 2007; Haubner *et al.*, 2001; Brown *et al.*, 2005). The SuDS philosophy of on site treatment both retains water on site, and reduces runoff velocities. This reduces the costs and impacts on downstream infrastructure e.g. bridges (ECONorthwest, 2007).

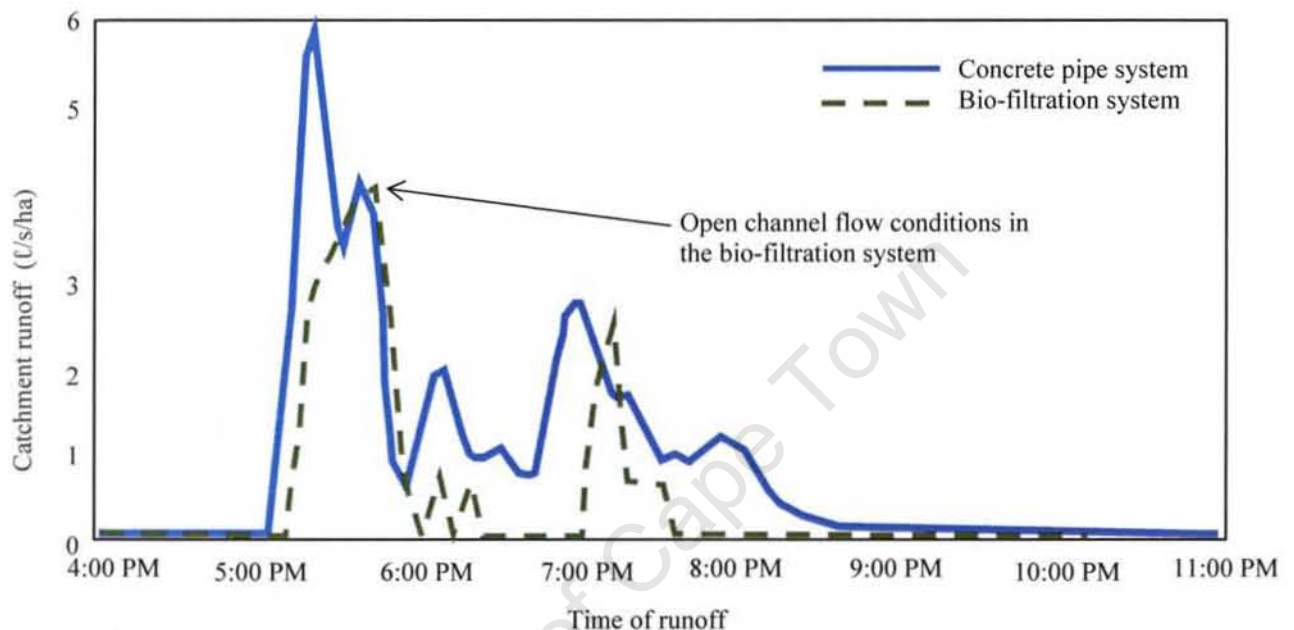


Figure 2-7: Comparison of discharge between a conventionally piped stormwater system, and one using WSUD principles (traced from Lloyd, 2004)

Figure 2-7 is taken from a study conducted by Lloyd (2004) that used Water Sensitive Urban Design (WSUD) principles to develop a site. The hydrograph above is a comparison between corresponding designs for the catchment. It is clear that the bio-filtration system delayed the flood peak in comparison to the conventional system. There is further evidence that the total runoff (area under the graph) and peak runoff is reduced although there are times where the two graphs coincide. This indicates that the formation of an open channel flow over the surface of the system has occurred (Lloyd, 2004).

2.4.2 Improved water quality

Buys & Aldous (2009) noted that stormwater is a major contributor to deteriorating water quality in the urban water systems of cities. It is widely accepted that SuDS has the ability to treat stormwater, and improve water quality (ECONorthwest, 2007; Minton, 2002) by capturing pollutants and treating them through physical, chemical, and biological processes depending on the technology implemented. This improved water quality is an environmental service that is essentially provided for free.

2.4.3 Increased ground water recharge

The South African government has identified ground water as a possible resource for supplying coastal cities as the potential to build dams decreases (Gosling, 2010). Research in Atlanta, USA by Otto *et al.* (2002) suggest that impervious surfaces have reduced ground water infiltration in Atlanta by 132 billion gallons a year (500 billion litres), the equivalent of 3.6 million people's water usage (ECONorthwest, 2007). Decreased infiltration results in the dropping of the water table, which in turn results in increasing extraction costs and limits extraction potential if environmental damage is to be avoided. Almost all SuDS make use of infiltration and have the potential to increase ground water supplies.

2.4.4 Infrastructural expenditure

While the ECONorthwest, (2007) study claims, and clearly supports the assertion that infrastructural expenditure may be reduced, a number reports including, but not limited to Lloyd (2004), ECONorthwest (2007) suggest that this is generally the case. Many of these case studies highlight one or two cases where the SuDS design has proved more expensive in terms of capital expenditure. A number of factors may influence the findings noted above. These include amongst others the costs of labour and technology that can vary greatly between the developed countries and the developing world. Section 2.7: Local economic factors: South Africa, discusses these factors in more depth.

2.4.5 Enhanced aesthetics & property values

In general increased urbanization has led to increased impervious surfaces e.g. pavements, roofs and driveways. These have the ability to increase runoff by up to a factor of 10 (Brown *et al.*, 2005). The goal of conventional drainage has been to remove runoff from an area as quickly as possible but has ignored, *inter alia*, the aesthetics of the stormwater system. It is generally accepted that water frontage and natural features add to the aesthetics of an area and consequently to the value of the properties in that area (ECONorthwest, 2007; US Department of Defense, 2004). A recently updated study by the US Department of Defense (2010) concludes that: "*In a variety of completed projects, micro-scale runoff management features have provided architectural interest in various forms...*" In Cape Town the rehabilitation of the Kuils River elevated property prices adjacent to the river by an average 10-12% (Van Zyl & Leiman, 2001). In a developing country such as South Africa this may put the cost of housing beyond what may be affordable to the poor.

While the increase in property values is desirable this does not apply to all SuDS technologies as some may in fact cause decrease in adjacent property values in case for example where detention ponds are not maintained and solid waste collect, or where mosquitoes present a health risk. Additionally, certain technologies take up more land than conventional systems, and this land also has value (Buys & Aldous, 2009). Consequently, there is a need to consider and balance this aspect through the combination of technologies. For example, green roofs manage stormwater without requiring additional land, reducing the

amount of land required for other controls (USEPA, 2000), an advantage for developers who are concerned about losing developable area. It has also been identified that “properly designed” controls may experience the “waterfront effect” that is commonly associated with natural water bodies. The value of this could range between 5-30% averaging at a 10% increase in the value of properties with a view of the water bodies (Buys & Aldous, 2009)). Additionally, in areas with excess properties for sale, waterfront properties experienced an increase in value. However Klein (2003) and Buys & Aldous (2009) found that dry ponds had the opposite effect to wet ponds and that property values were 4-10% lower. The point about dry ponds is reinforced by research in Illinois that also indicated the perceived negative effect of their construction (Buys & Aldous, 2009). Table 2-9 is compiled from USEPA (1995) and indicates which factors related to drainage tend to lead to an increase or a decrease in property values.

Table 2-9: Factors affecting property values

Factors affecting property values	
Increases	Decrease
Naturally designed water bodies (Wet Ponds)	Open, unprotected water is a concern to residential owners with young children - drowning hazard
Ponds & lakes create ideal scenery for business parks	Poor design/aesthetic appeal (dry ponds)
Positioning, features near entrances increase sale and value of properties	Safety concerns, main negative effect of stormwater controls
Property with water views or other amenities can be charged premiums	Poor maintenance leads to unsightly wet/dry ponds due to excessive algal growth or garbage build-up.
New recreational facilities (paddling, open areas etc.)	Health concerns (mosquito breeding grounds.)

2.4.6 Reduced energy consumption

“Vegetated roof covers in urban areas offer a variety of benefits, such as extending the life of roofs, reducing energy costs” (USEPA, 2000). The reduction in energy costs is related to the reduction in ambient temperature and a result of the insulation offered by green roofs. The ability to reduce ambient temperatures has recently been confirmed in a study for the eThekweni Municipality. The study showed that the use of green roofs decreases the air temperatures and insulates the roof (Greenstone, 2010). This insulation effect can reduce energy requirements of entire buildings (ECONorthwest, 2007) while concurrently reducing pollution and improving aesthetics (US Department of Defense, 2010).

2.4.7 Who Pays?

The “polluter pays” principle is widely accepted in law and therefore it is appropriate to account for the cost of treatment. Hunter City Council (2007) summarizes the most important aspects in relation to the valuation of assets and services:

- *“polluter pays—that is, those who generate pollution and waste should bear the cost of containment, avoidance or abatement;*
- *the users of goods and services should pay prices based on the full life cycle of costs of providing the goods and services, including the use of natural resources and assets and the ultimate disposal of any waste; and*
- *environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, that enable those best placed to maximise benefits or minimise costs to develop their own solutions and responses to environmental problems.”*

These views are widely supported in the literature. Lampe *et al.* (2005) emphasize the need to consider EGS as part of any analysis. In conventional systems, these costs are currently being externalized onto the environment resulting in the potential for the loss of natural capital. The whole life cycle of drainage designs are often not considered.

2.4.8 What is required in a model for South Africa?

The model needs to:

- Account for the numerous EGS associated with SuDS but not associated with conventional systems;
- Ensure a fair comparison between SuDS and conventional systems by accounting for the EGS associated with SuDS ;
- Permit the user to determine who pays as well as what is being paid for; and
- Account for all ‘costs’ over the life cycle.

2.5 Infrastructure economic assessment

2.5.1 Economic assessment

Gordon *et al.* (2002), Kuprenas *et al.* (2003) and Gordon *et al.* (2004), proposed a methodology for analysing the costs of advanced treatment in the Los Angeles area. Applying this methodology they considered the impacts on the economy of implementing stormwater treatment to meet the local water quality requirements to three different levels within in the Los Angeles area. Numerous authors have presented methods and data for undertaking Life Cycle Cost Analyses (LCCA), however these methods consider only monetary aspects ignoring the impacts of externalizing treatment onto the environment, or treating stormwater on a regionalized basis. Some studies, such as Kirk (2006), have undertaken Life Cycle Analyses (LCA) that have the potential to consider the total environmental benefits and all aspects of the life cycle. These studies are however site specific, hence their use in

predevelopment decision-making is limited. It is therefore important to define what type of analysis is to be undertaken. Figure 2-8 highlights a number of factors that should be considered as part of an analysis of a stormwater system.

A review of the literature indicates three common approaches used to evaluate these factors in economic studies of SuDS and conventional drainage systems. These are:

- i) Analysis of the capital/construction costs (CCA);
- ii) Analysis of the Life Cycle Costs (LCCA); and
- iii) A comprehensive benefit cost analysis (BCA).

Each of these three techniques has different advantages and shortfalls as summarised in Table 2-10.



Figure 2-8: Factors to be considered in an Economic Analysis

Table 2-10 indicates that a CCA would be relatively simple to complete in South Africa where there is limited life cycle costing data. Due to the limited outputs, it would however be of relative insignificance to the majority of stakeholders. On the other hand, Figure 2-9 indicates that the output from a comprehensive BCA would be optimal for decision makers due to the comprehensive nature of the study; however, the drawbacks in terms of cost, the lack of available data and time constraints, limit its application in this research. It is also often difficult to assess all the benefits. For the purposes of this research, the LCCA analysis is most appropriate as sufficient data is available to undertake the analysis. The LCCA may be undertaken within a reasonable time frame. This is in line with international studies where the majority of the studies are based either on capital/implementation costs or life cycle costs as discussed above, with a qualitative assessment of the risks, and environmental benefits

(ECONorthwest, 2007). Certain additional considerations will be included to achieve a fair evaluation of the different techniques:

- Ensuring that both conventional and SuDS techniques have equivalent effluent qualities;
- Ensuring that peak flows are equally reduced; and
- Ensuring that the design of conventional drainage does not influence the design of SuDS or vice versa.

Table 2-10: Techniques for analysing drainage economics

Techniques for analysing urban drainage economics	
Advantages	Disadvantages
Capital Cost Analysis (CCA)	
One of the most common studies	Considers only capital costs
Requires the minimum inputs	Ignores benefits
Can be completed easily	Goods & Services
	Does not take account of effectiveness of system
	Different stakeholder will want different information
Life Cycle Cost Analysis (LCCA)	
Considers whole life cycle costs from design to decommissioning	Still excludes economic benefits of the construction
Intermediate assessment	Can be done on a case study basis. In SA rather unlikely as the systems are not old enough to allow for collection of sufficient information
Benefit Cost Analysis (BCA)	
Comprehensive analysis	Requires more data and time, and costs more to produce
Considers all economic benefits and costs	

2.5.2 Life Cycle Cost Analysis

Life Cycle Costing (LCC) is “*the systematic consideration of all relevant costs and revenues associated with the acquisition and ownership of an asset*” (Clift & Bourke, 1999). Life cycle costing essentially considers all the costs associated with an asset. In terms of SuDS, this would include design, construction, establishment of vegetation (SuDS option dependent), maintenance (inspections, regular, irregular, and corrective), disposal and land costs. These costs, and any benefits, are all discounted to their present value. There are two possible LCCA that may be undertaken viz. an economic or a financial analysis as indicated in Figure 2-9. A financial appraisal considers only the monetary costs associated with an asset’s life cycle whereas; a ‘full’ economic appraisal considers both the monetary and the non-monetary costs over the assets’ lifecycle. Non-monetary costs include the environmental costs and benefits which may be economically appraised and included in the analysis.

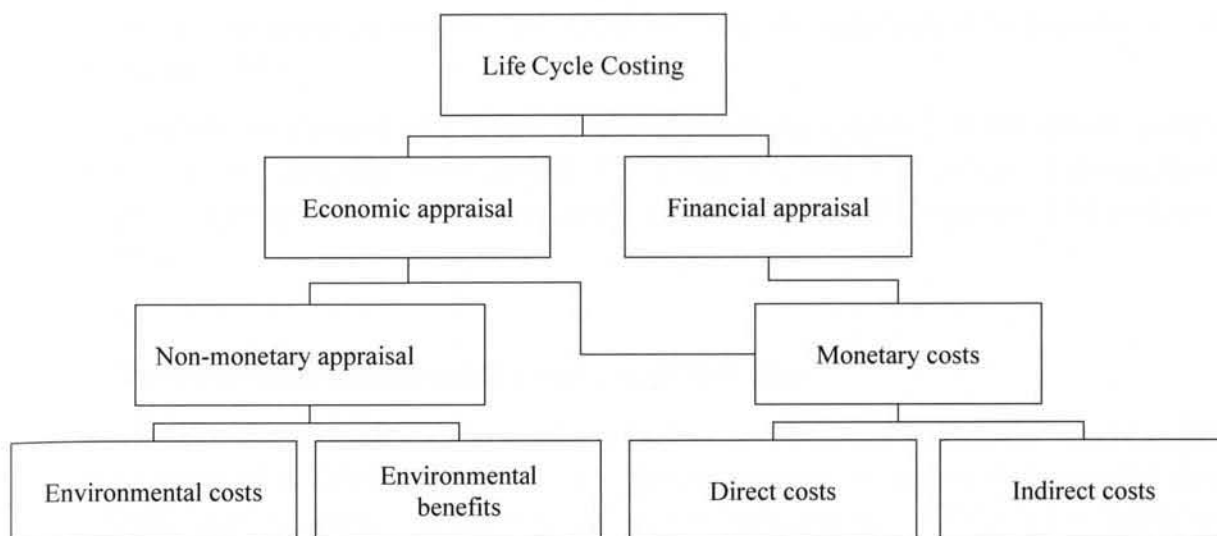


Figure 2-9: Approaches to Whole Life Cycle Costing (After Lampe *et al.*, 2005)

2.5.3 Estimating Financial Costs

The following five approaches may be used to estimate the cost of infrastructure:

- i) Bottom-up cost estimate – requires the identification of all costing components of a project or a design, and then the summation of these costs, to determine a total project or design cost (Narayanan & Pitt, 2008). It is not always appropriate for a LCC where data, time or personnel are limited (US Department of Defense, 1995).
- ii) Top-down cost estimate – considers the overall characteristics of the project (US Department of Defense, 1995). “Costs of the entire project are estimated by partitioning the project into lower level components and lifecycle phases beginning at the highest level (Narayanan & Pitt, 2008).”
- iii) Expert judgment – is a process of consulting with “experts” within a field. The estimated cost of a project or design is based on the experience of the expert (US Department of Defense, 1995). While expert judgment is useful, and compliments other estimation techniques, it is limited to the “expertness” of the expert. This point is highlighted by Bowers (1998) in reference to environmental costs. Bowers (1998) questions what qualifies the “expert” to estimate a cost to the environment. In an economic analysis that considers the environmental costs and benefits, this method could be “discredited” and considered inappropriate.
- iv) Analogy – is a method that attempts to draw comparisons with previously completed projects thereby extrapolating a cost from the available data on the previous projects (Narayanan & Pitt, 2008; US Department of Defense, 1995). The major benefit of this method is that it is based on actual cost data, however old. If correctly applied and appropriately adjusted it can result in appropriate estimates. The method falters where

there are no previous projects on which to base the estimates (US Department of Defense, 1995).

- v) Algorithmic or Parametric – reduce historical data into equations. These equations can have multiple variables (Narayanan & Pitt, 2008). The major advantage of this method is that unlike expert judgment, the results are repeatable (US Department of Defense, 1995).

2.5.4 Value of Environmental goods and services

Few studies consider the environment. The valuation of environmental goods, services and impacts is a specialized field. This section provides an overview of how environmental goods and services may be valued in order to allow for inclusion in a LCCA of a SuDS or conventional system. While it is possible to identify the benefits (externalities), attaching economic value to them is not simple (Lampe *et al.*, 2005). A number of techniques are available for valuing environmental goods and services. Table 2-11 highlights the various methods available. Three are relevant to this thesis. These are: Substitute Cost/Replacement Cost, Expert Judgment and the Contingent Valuation Method

The Cost of Replacement is a method that determines the cost of relocating/developing an equivalent site elsewhere. In the case of environmental cost, the “compensation” is not always made, nor is it given to compensating the environment. If it were, there would be no environmental damage or costs (Bowers, 1998).

The use of this method is further supported by Smit *et al.* (2002) who state: “*Open space and catchment managers could use this methodology to compare the annual management and operation costs with the replacement cost and value of these systems. Furthermore, this type of data could be used to motivate for resources to ensure that future engineering solutions will not be required to replace degraded natural systems no longer able to provide the required services to the CCT.*” Turpie *et al.* (2000) and Harding (2001) have used it locally for valuing wetlands in Cape Town. The Contingent Valuation Method (CVM) considers the public’s willingness-to-pay for a change in the quality or quantity of an environmental good or service This will be area specific (Lampe *et al.*, 2005) and requires investment in surveys. The purpose of this study is to compare the systems on an equal basis. The value of utilizing a society’s willingness to pay, especially in an economic downturn, is of questionable value.

It is possible to use multiple techniques, either to compare outcomes or to complement each other as was done in the study by Narayanan & Pitt (2008). The method or methods selected need to consider the constraints of the project in terms of data (historical & current), experience, time and personnel.

Table 2-11: Economic valuation techniques (Pagiola *et al*, 2004)

	Method	Approach	Use
Revealed preference method	Production function (also known as 'change in productivity')	Traces impact of change in ecosystem services on produced goods	Any impact that affects produced goods
	Cost of illness, human capital	Traces impact of change in ecosystem services on morbidity and mortality	Any impact that affects health (e.g. air pollution)
	Substitute /replacement cost	Uses cost of replacing the lost goods or service	Any loss of goods or services
	Travel cost (TCM)	Derives demand curve from data on actual travel costs	Valuing recreational activities
	Hedonic pricing	Extracts effect of environmental factors on price of goods that include those factors	Air quality, scenic beauty, cultural benefits
Stated preference methods	Contingent valuation (CV)	Asks respondents directly re willingness to pay for a specified service	Any Service
	Choice modelling	Asks respondents to choose their preferred option from a set of alternatives with particular attributes	Any Service
Other	Benefits transfer	Uses results obtained in one context in a different context	Any for which suitable comparison are available
	Expert Judgment	Based on the experience of the expert.	Any Service

2.5.5 What is required in a model for South Africa?

The model:

- Needs to be flexible and accommodate costs calculated utilizing different valuation techniques;
- Consider the whole life cycle; and
- Account for EGS in line with appropriate economic principles (Either: Substitute Cost/Replacement Cost, Expert Judgment or Contingent Valuation Method).

2.6 International studies considering stormwater economics

2.6.1 Overview of international case studies

SuDS is relatively new to South Africa. As with many new technologies of this type there is a degree of scepticism and many impediments preventing their wide spread application (CIWEM Conference 2005, 2005). Amongst these is concern about maintenance and associated costs. This is a result of a lack of LCC data (Taylor & Fletcher, 2006; CIWEM Conference 2005, 2005). Local conditions in South Africa, catchment conditions on site and many other external factors will influence the LCC of both SuDS and conventional systems.

There is value in considering international experiences and what has influenced the LCC of SuDS internationally.

SuDS technologies have been extensively implemented in 'developed countries'. Internationally number of studies have been undertaken to assess the economic implications of implementing 'SuDS type technologies'. Different regions term and or conceive of SuDS slightly differently, such as: Low Impact Development (LID's), Better Management Practises (BMP's) etc. In general, the concepts are comparable although not always interchangeable. Table 2-12 below is a selection of reports from international authors and includes their conclusions with respect to comparing conventional and alternative stormwater strategies.

Table 2-12: Comparative studies: Alternative vs. Conventional stormwater systems

Source	Country	Report's Economic Conclusions
Boubli <i>et al.</i> , (2003)	Aus.	Based on the above discussion it appears that a WSUD can be delivered on most projects without imposing a cost burden. In fact a balanced WSUD may be cost neutral on smaller projects but is likely to deliver increasing savings on larger projects.
Lloyd S.D, (2004)	Aus.	"Bio-filtration systems provide a 25% saving to the community compared to treating runoff conventionally at a downstream constructed wetland. Additionally research found 85% of homebuyers supported the introduction of this technology in their neighbourhoods"
Sidek <i>et al.</i> , (2004)	Malaysia	The finding of the study was that MSMA (environmentally friendly drainage) was 5% less than that of conventional systems
Coombes <i>et al.</i> , (2004)	UK	"The benefits of WSUD source control approaches arise from reduced mains water use and reduced stormwater infrastructure...In addition, the case study demonstrates that use of WSUD source controls including rainwater tanks in new urban development's offers the economically most efficient infrastructure solution providing benefits to the community of up to \$6B in the Lower Hunter Region and up to \$5B in the Central Coast Region."
Narayanan, (2006)	USA	In a comparison of conventional systems and grass swales systems, grass swales appeared to approximately a fifth of the cost over the life cycle.
USEPA, (2007)	USA	"The 17 case studies presented in this report show that LID practices can reduce project costs and improve environmental performance. In most cases, the case studies indicate that the use of LID practices can be both fiscally and environmentally beneficial to communities. "
ECONorthwest, (2007)	USA	A review of the economics of LID's in the USA. It generally found, with notable exceptions, that LID's were more economical.

Overall Table 2-12 appears to indicate that SuDS are usually, but not always, more economical than conventional systems. In the extreme scenario, conventional systems may cost twice that of SuDS over the lifetime of the project. It is however important to identify 'who pays for what?'. SuDS require on-going, regular maintenance. A relatively higher proportion of the costs might be contained within this particular item. It is important to emphasize that Table 2-12 does not consider studies that only considered capital costs as these studies are often misleading. Land costs are seldom considered. It is worth noting that variations in capital costs may be relatively large as is shown in Table 2-13. Variations in savings range between +76% to 96% savings, the majority of which are greater than 0%.

These results may seem to support the use of SuDS, however they remain misleading as the burden of the on-going O&M is predicted using limited data.

Table 2-13: Summary of Cost Comparisons (USEPA, 2007)

Project	Conventional Development Cost	LID Cost	Cost Difference	Percent Difference
2nd Avenue SEA Street	\$868,803.00	\$651,548.00	\$217,255.00	25%
Auburn Hills	\$2,360,385.00	\$1,598,989.00	\$761,396.00	32%
Bellingham City Hall	\$27,600.00	\$5,600.00	\$22,000.00	80%
Bellingham Bloedel Donovan Park	\$52,800.00	\$12,800.00	\$40,000.00	76%
Gap Creek	\$4,620,600.00	\$3,942,100.00	\$678,500.00	15%
Garden Valley	\$324,400.00	\$260,700.00	\$63,700.00	20%
Kensington Estates	\$765,700.00	\$1,502,900.00	-\$737,200.00	-96%
Laurel Springs	\$1,654,021.00	\$1,149,552.00	\$504,469.00	30%
Mill Creek	\$12,510.00	\$9,099.00	\$3,411.00	27%
Prairie Glen	\$1,004,848.00	\$599,536.00	\$405,312.00	40%
Somerset	\$2,456,843.00	\$1,671,461.00	\$785,382.00	32%
Tellabs Corporate Campus	\$3,162,160.00	\$2,700,650.00	\$461,510.00	15%

In LCCA's (Table 2-12) SuDS designs have generally been found to be more economical than conventional approaches, the degree to which this is the case varies from 5% to 25%. It is important to recognise that these studies are not a case of two identical sites being developed; but a hypothetical situation where either one or neither design is implemented. Consequently, the value of contingencies in the estimate should be considered. This often ranges between 10-30%, which should place many studies estimates in a new light. It is also worth noting that the experience of both designers and contractors will influence the economics of a design as highlighted in Section 2.3. This is of relevance in South Africa where SuDS is relatively new to all role players.

Section 2.4 highlighted the value of EGS and the need to fairly compare drainage systems. Incorrect conclusions will be reached if a LCCA is conducted without considering the significant costs that are externalized onto the environment by conventional systems. Many analyses fail to consider any costs or benefits beyond monetary costs. The validity of these results could be questioned.

A significant problem when utilizing international studies revolves around a question of fairness and relevance to South Africa. As an example, the study by Narayanan & Pitt (2008) detailed the full design of which the following two points are notable:

- i) The cost of maintenance of the conventional system was estimated, although no background to this figure was given; and

- ii) The design made use of a 1700 ft long (520m), 50 ft (15m) wide swale with natural buffers of 50 ft (15m) on either side.

Firstly, no reputable guidelines suggest the design of a 15m wide swale. Secondly, the swale and associated buffer strips require 45m servitudes. That is not practical from a land take point of view and would significantly influence the income of a developer, something that was not accounted for. Swales are generally a “cheap” SuDS option and the ‘exploitative’ use of swales in this design will clearly result in a cheaper option. The credibility of this design is questionable, especially for translation to South Africa. This case study did not consider the environmental impacts of the conventional design. While international case studies may offer trends and ideas, unless independent verification is possible, the proposed designs should not be used to motivate arguments supporting the economics of SuDS.

The discount rate is a point that is seldom considered in these studies. As the discount rate varies, the viability of each system varies. This is highlighted in Sidek *et al.* (2004), who carried out a sensitivity analysis and found as the discount rate increased the difference in life cycle costs decreased, as shown in Figure 2-10. The lower the rates the more economical the MSMA (SuDS) approach was, and inversely the higher the rates, the less economical. Further discussion of discount rates is contained in Section 2.7.

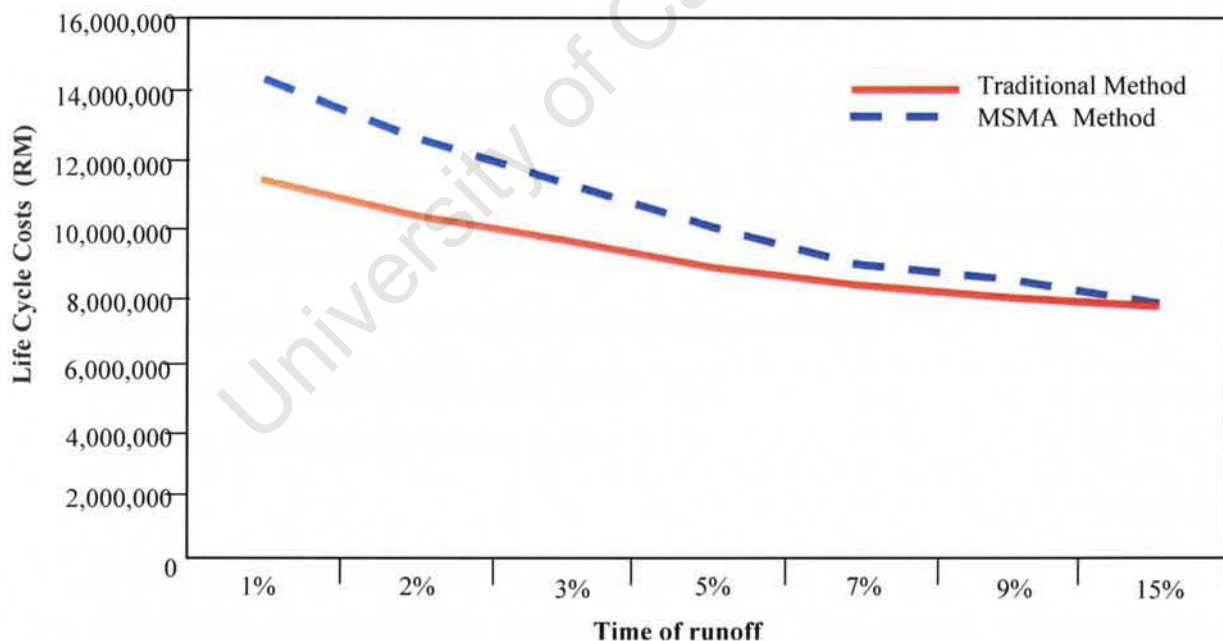


Figure 2-10: Impact of Discount Rate on comparative studies
(traced from Sidek *et al.*, 2004)

2.6.2 Challenging perceptions of SuDS

Perceptions are an important consideration. They influence both the selection of the drainage system and the value stakeholders place on different aspects. Internationally, as these technologies came to prominence, there was a general lack of understanding both from the public and developers/builders (ECONorthwest, 2007). This potentially gives rise to the incorrect choice of technologies or failure to adopt a multidisciplinary approach. Perceptions that the construction of SuDS is difficult or more costly may exist. Lloyd *et al.*, (2002) concluded after his study that “*Construction of the stormwater management scheme was no more difficult than for conventionally designed stormwater drainage systems*”.

Developers may express concern that SuDS technologies may occupy more space decreasing the developable area (Buys & Aldous, 2009; ECONorthwest, 2007). The concern is real, however, developers may be reassured that the SuDS if correctly implemented it will likely add value to their properties.

The argument frequently raised in the literature is that SuDS technologies are a challenge to the “dominant logic” and consequently there are groupings that approach SuDS with scepticism. It is important that all sectors, both public and professional, are educated as to how these systems should and can function (Berdier & Toussaint, 2007). There are cases where SuDS would be inappropriate and conventional systems may need to be used, for example on steep slopes or high risk areas. In these cases quality, quantity and amenity need to be considered economically.

2.6.3 What is required in a model for South Africa?

The model should:

- Have the capacity to compare the systems on a fair basis i.e. include and account for relevant environmental goods & services;
- Provide designs that are fair, appropriate and implementable;
- Consider the whole life cycle of the system; and
- Allow for the variation of discount rates.

2.7 Local economic factors: South Africa

This review has predominantly focused on the economics of stormwater, and the different alternatives that may be used in the management of stormwater. It is important that the context within which the alternatives are being considered is fully understood. The following section deals with the current state of affairs in South Africa where it has been stated that “*It can be assumed that a national problem with water quality and quantity would affect the South African economy in the same way that the recent energy shortage, which resulted in a drop in economic growth of at least 2%, to the value of around R45 billion*” (van der Merwe-

Botha, 2009). Additionally stormwater is a major cause of poor water quality (Buys & Aldous, 2009). The question has to be asked whether at this point in time investment in stormwater management is affordable; while simultaneously considering the long term costs and benefits.

The discussion that follows reviews the current economic climate, as well as factors in South Africa that may directly influence both the analysis and the uptake of progressive stormwater management approaches. The importance of dealing with quantity as well as quality is addressed.

2.7.1 Selecting an appropriate discount rate

“The discount rate is the rate used to convert all future costs and benefits to present value so that they can be compared” (Lampe *et al.*, 2005). It is considered to be the difference between the rate of return on the open market and inflation. In the UK the discount rate is traditionally set by the national treasury, however in the USA and South Africa this is not the case. In 2010, the White House Office of Management and Budget (USA) recommended a Real Discount Rate of 2.3% for projects of 30 years or longer (Lew, 2010). In the USA water utilities have traditionally used the average cost of borrowing less inflation as their discount rate (Lampe *et al.*, 2005). In South Africa the national treasury does not prescribe the discount rate, however states:

“For practical purposes, the discount rate is assumed to be the same as the risk adjusted cost of capital to government. The government bond yield has been used by some institutions as the discount rate for a particular project over a comparable period. The argument in favour of using the government bond yield is that it reflects the actual cost to government of raising funds at any given time. This ignores a number of factors that are difficult to quantify, including: various risk margins relating to increased government borrowing; various tax implications of diverting funds from private to public consumption; and government’s time preference of spending.”
(National Treasury, 2004)

It is up to the institution or person modelling the project’s feasibility to determine and motivate the discount rate being used. The Construction Industry Development Board (CIDB) refers to the National Treasury definition when applying a discount rate. The CSIR (2000) makes use of a discount rate of 8% for road construction, although state that it is necessary to conduct a sensitivity analysis for 6.8% – 10%. The use of the South African Bond Yields (8% to 9% for the period 2010-2011 (Trading economics, 2011) and an inflation rate of 5% (Statistics SA, 2011)) would result in a discount rate of approximately 3% to 4%.

Selecting an appropriate discount rate is extremely important and contentious issue in LCC (Lampe *et al.*, 2005). The discount rate can have an effect on the outcomes and many studies therefore recommend a sensitivity analysis with varying the discount rate. This point is illustrated in Figure 2-11 where the discount factors clearly show a decreasing value of

money over time. More importantly the difference between discount factors increases over time. A discount factor is calculated using Equation 1.

$$PV = \frac{I}{(1+i)^n} \quad (1)$$

Where PV = Present Value; I = Interest rate (annual); n = number of years; i = discount rate

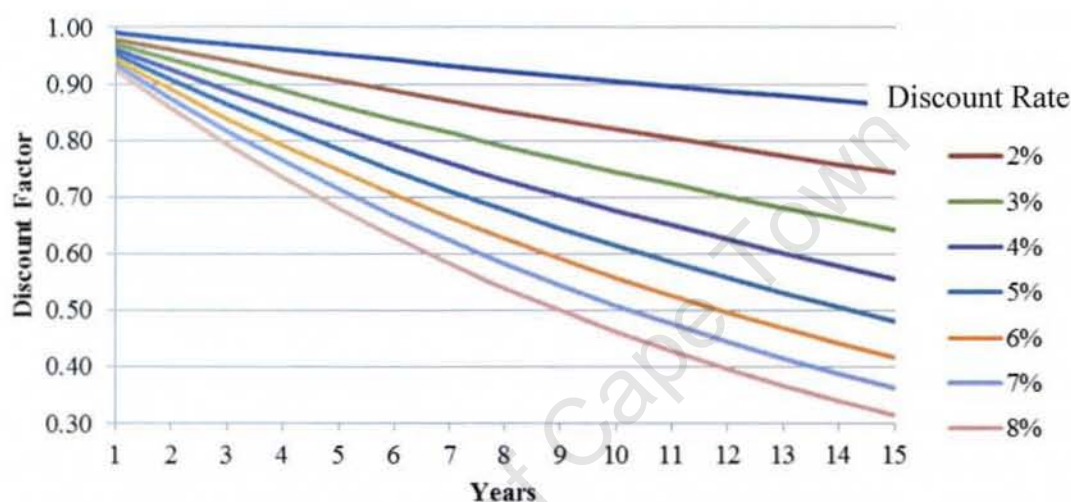


Figure 2-11: Present Value discount factors over time

Sidek *et al*, (2004) indicate a higher discount rate should be advantageous for SuDS when conducting a LCCA. This is likely due to two factors. Firstly, SuDS have generally been found to have a lower capital cost (see Section 2.4.8) while having higher maintenance costs. When maintenance and operating costs over a lifetime are brought to a present value, the interest rates play a key role. Figure 2-11 shows the discount factors used to bring/convert a future payment/expenditure into its current value by multiplying the discount factor by the 'cash value'. Higher discount rates in effect result in a 'lower future cost'. Therefore the balance between SuDS's capital and O&M may be its advantage in an economic comparison with conventional systems.

2.7.2 Local labour market

Due to the "soft" nature of SuDS, there is an associated and increased need for maintenance. The maintenance required is fairly simply e.g. cutting grass, removal of litter, removal/replacement of soil etc. The labour market therefore has an important and potentially large impact on the LCC of SuDS; consequently it is important to consider the local labour

market, minimum wages etc. South Africa has a large pool of unemployed persons who would benefit from the opportunities that SuDS could offer. In the second quarter of 2011 South Africa had an 25.7% official unemployment rate (Statistics South Africa, 2011) which indicates that there is large pool of potential labour that could benefit from the labour intensive maintenance operations that SuDS supplies. This could potentially be used as a selling point for government to introduce SuDS to assist in job creation.

South Africa has a range of legislation dealing with labour relations, amongst these the Labour Relations Act, the Basic Conditions of Employment Act etc. While the legislation serves to protect employees, it is commonly seen as a hindrance to investment in the country. An additional consideration is the fact that South Africa labour is strongly unionized with even military personnel belonging to a union. The unions have in the past demonstrated that they can become very militant, embarking on strike action and even supporting workers from other sectors through strike action. Referring to recent political and social problems within the country, Pringle (2010) states: “ *the recent local taxi and labour strikes did not bode well for investor perception....*” This should be considered when making decisions regarding infrastructure, especially where lack of maintenance or operational work (cleaning of gross pollutant traps) results in a risk to the public health and safety. This is especially important in South Africa “*as labour legislation makes it difficult and cumbersome to discipline negligent or obstructive staff*” (van der Merwe-Botha, 2009).

Additionally there is evidence of inflated wage expectations (reservation wages) amongst South African's unemployed and labour force. This is evident in a report by Kingdon & Knight, (2001) that “*about half of the jobless had reservation wages that were higher than the wage they could reasonably expect in wage employment*”. They do however state “*it is doubtful that many of these were voluntarily unemployed*”. This considered, it could account for the annual strikes where on a yearly basis, higher wages are demanded in South Africa. The hourly wage attributed to inspections and maintenance will be an important factor when the operating and maintenance costs are considered and the level of expertise required would need to be determined. Lampe *et al.* (2005) suggest hourly labour costs for the USA of \$15 – \$40. This in South African terms would equate to a monthly salary of R20,000 – R53,000 (SA-Venues Exchange, 2010). This is on the upper end of the South African labour market. Table 2-14 indicates the South African minimum wage. It is likely that the majority of maintenance in South Africa will take the form of manual, unskilled labour with skilled supervision and that the minimum wage in the construction sector could be attributed to a large portion of the maintenance completed.

Table 2-14: Industry specific minimum wage 2009/2010 (My Wage, 2010)

Industry	Sub-sector	Occupation	Hours of work per week	2009/ 2010 Monthly wage (Rand)	Approximate hourly wage 2009/2010
Construction	Building	Labourer	40	1,998	12.5
Construction	Building	Labourer/Cleaner	44	2,320	13.2
Construction	Building	Labourer/Cleaner	44	1,920	10.9
Construction	Building	General Worker	44	2,661	15.1
Construction	Building	Construction Worker Level E	45	2,090	11.6
Construction	Building	General Worker	45	1,434	8.0

2.7.3 Municipal Rates

A factor that must not be overlooked in this debate is the ability and willingness of stakeholders to pay for stormwater management. While stakeholders may accept that there are legal, social, ethical and even medium to long-term economic advantages to the effective treatment of stormwater, the short-term investment required may simply be too much of financial burden. In retrofits this may be the case, however research in Brazil suggests that SuDS has the potential to decrease the investment requirements (Nascimento *et al.*, 2005).

If for social, technical or economic reasons conventional systems, which have a proven track record (in South Africa), prove to be viable, or could be implemented in phases i.e. while during periods of economic distress, quantity is managed effectively. When financially sound water quality can be considered. This may be the more acceptable result. As with the “Goods & Services” supplied by SuDS systems, these factors must be considered, even if they cannot be quantified.

Stormwater financing is currently built into the general rates, and not as a separate fee with the stormwater department having to motivate for resources. This makes it difficult to motivate to the public that there is a financial/economic need to increase funding for stormwater management as it is assumed that this is already addressed. It is consequently possible for municipalities to disguise the inadequate funding of stormwater, as indicated in Table 2-16. Table 2-15 indicates the expected increases in municipal rates for the City of Cape Town, one of South Africa’s six Metros. It is important to note that for the 2010 financial year the rates and service fees all increased at above the official rate of inflation, some instances 3-4 times the rate of inflation. This might in the long term influence resident’s ability and willingness to pay for stormwater management – however important they judge proper stormwater management to be.

Table 2-15: Expected increase in rates in the City of Cape Town
(City of Cape Town, 2010)

Item	Increase 2010	Comments
Water & Sanitation	10%	Above inflation*
Electricity	24,6%	2010 four times inflation*
Solid waste removal	18%	2010 3 times inflation*
Stormwater	0%	South African Municipalities do not currently directly charge for stormwater management
Property Rates	9.3%	Above inflation*

*Inflation 5.7% in February 2010 (Statistics SA, 2010)

Table 2-16: City of Cape Town stormwater budget & budgetary requirements
(Arnold, 2009)

Budget and budgetary requirements		
Category	Budget	Comments
Required O&M	R400 Million	Note this is only for conveyance and quantity management
Current O&M	R46 Million	Note this is 10% of the required amount required.
Capital Budget	R1200 Million	Note this is an estimate for quantity management only over a period of 10 years and accounts for the backlog in infrastructure

2.7.4 What is required in a model for South Africa?

The model needs to allow for sensitivity analyses to be undertaken by varying the discount rate.

2.8 Cost modelling tools

2.8.1 WERF Cost spreadsheets (Lampe *et al.*, 2005)

The Water Environment Research Foundation (WERF) Life Cycle models are one of the simple but most extensive models available. They are the result of an extensive study by Lampe *et al.* (2005). The Excel based models are based on extensive research into the performance of SuDS and their life cycle maintenance requirements and the associated costs in response to the lack of knowledge in this area. Five separate models were developed for: swales, retention ponds, detention ponds, permeable pavements, and filter drains. A more recent WERF project developed models for rain gardens, in curb planters, curb contained bio retention units. The models allow the user to calculate capital costs over a maximum of 50 years based on either catchment characteristics, or user inputs. Maintenance costs are based on the results from the WERF (2005) research although user override is allowed. The results are entered into a life cycle costing module as shown in Figure 2-12.

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective Maint.	Total Costs	Present Value of Costs	Cumulative Costs			
							Cash	Present Value	Discounted Cost per Year	
Cash Sum (\$)						\$ 81,883	\$ 40,245			
0	1.000	\$ 18,719			\$ 18,719	\$ 18,719	\$ 18,719	\$ 18,719	\$ 40,245	
1	0.948	\$ -	\$ 980	\$ -	\$ 980	\$ 929	\$ 19,648	\$ 19,648	\$ 21,528	

Figure 2-12: WERF 2005 Life Cycle modules (Lampe *et al.*, 2005)

Two versions were created, one for the USA and one for the UK. While the USA versions are freely available, the UK versions are cost approximately US\$200.00. The UK versions do include the following additional tools:

- Design calculations;
- Associated design costs (flood risk management, overheads and land costs);
- Guidance on environmental and damage costs based on typical unit costs;
- Environmental costs may be included in the modelling but are not applicable to South Africa the user is required to consider the local factors; and
- Performance ranking tool.

Lampe *et al.*, (2005) emphasises the need to consider the environmental goods and services, and the differences between conventional systems and SuDS systems. While the research presented is invaluable, and the models are very useful, there are a number of problems associated with using these models in South Africa, as is discussed below:

- The models can only consider one life cycle, and offer no guidance as to the expected useful life of components. The models run the life cycles over 50 years regardless of the component;
- The models are independent. This requires users to conduct their own calculations to convert the results from a number of these models to the same life cycle. The results must then be combined into a total system cost;
- The models require the users to calculate the costs of the SuDS system at its different scales;
- The valuation of environmental goods and services is based on very limited research with great variation in results; and
- The models cannot be used for running analyses for conventional systems, or for conducting comparisons between systems. The models are essentially useful for conducting comparisons between technologies.

2.8.2 Green Values Stormwater tool box

The Green Values Stormwater Tool Box is a relatively new tool. It is an internet based calculator that estimates the monetary and the environmental costs and benefits of conventional and SuDS drainage options (GVSC, 2011). While it is very useful, it has a number of disadvantages:

- Being internet based, the inputted data may not be saved (GVSC, 2011);
- The data is based on American experience;
- The valuation of benefits is not based on site characteristics, nor on local data, but is related to the treatment of waste water that follows a treatment process that is not necessarily the least cost; and
- Valuations are based on limited data e.g. valuation of flood protection is based on two sources (GVSC, 2011).

2.8.3 MUSIC

MUSIC is a software package used for conceptual design. The software does have the additional ability to conduct life cycle analyses (Music, 2009). While the software is extremely useful, the inbuilt data is based on Australian experience (Music, 2009) and hence is not necessarily relevant in South Africa. While local data could be input, this data is currently not available. Another disadvantage of the software is its cost at R14,000.00 for a single computer license, which would potentially be a barrier to its wider use for non-engineers and small engineering practises (eWater, 2011). Additionally no benefits may be considered. The software does allow the user to consider costs verse volume of pollutant removed, however there is little data in South Africa to indicate what the runoff concentrations are, nor the removal efficiencies of the SuDS options. MUSIC does allow the user to consider the costs at different points of the treatment train, a useful tool in recognising who is responsible for what costs. While a very useful tool, the application of MUSIC in South Africa will not result in a 'fair and equivalent' analysis.

2.8.4 Rainwater Harvester

The Rainwater Harvester software (Jones, 2008) is a useful piece of software for considering the costs and benefits of Rainwater harvesting and reuse. It has built in rainfall data for a number of cities in the USA. It does however have one major weakness for use in South Africa and that is the use of imperial units, which would require the conversion of all SA data into these units and then the results back to SI units. This would not be user friendly, nor practical for the wider use of SuDS in South Africa.

2.8.5 ECO.SWM

ECO.SWM is a LCCA tool for stormwater management that was developed for the SWITCH research project. The tool is linked to an online database based on European data, the relevance of which is doubtful for reasons already discussed. Only Switch project members are able to edit the database although “guests” have limited access and rights (Seiker, 2007). ECO.SWM purports to calculate the net present value, however it is not possible to account for any non-monetary costs or benefits, and thus the analysis is simply a present value analysis. ECO.SWM allows for a number of scenarios to be developed for comparison.

ECO.SWM is essentially a standard LCCA tool unable to account for environmental goods and services. The model therefore fails to meet the important requirement of being able to compare to systems on a fair and equivalent basis.

2.8.6 General

There are a number of models available for undertaking life cycle cost analyses. A select number have been developed to consider costs and benefits, but none of these do so in a ‘fair and equivalent’ manner, in line with economic principles. Additionally none of these models could be widely applied in South Africa due to the variations in climate and the site characteristics, and the use of non SI units which would not be user friendly.

2.9 Conclusion

Society has to make a paradigm shift and refrain from externalizing the costs of sustaining current practices onto the environment. Some civil engineering consultants in South Africa argue that it is too impractical, too expensive and economically unviable to treat stormwater. There is a need for a model to assist in decision making. Internationally a number of models are used for conducting comparative economic studies. Many of these models are based on historical data and monitoring. As highlighted above, there are a number of reasons why these models would be inappropriate for South Africa. If SuDS are to be implemented in South Africa, barriers such as the uncertainty of life cycle costs need to be removed and a model that allows for the objective and unbiased comparison of SuDS and conventional drainage systems needs to be developed. Such a model would need to be appropriate to the South African context.

A number of factors needed to be considered when assessing whether the current models are appropriate or whether a new model is required. These are summarized in Table 2-17.

A particular need is the ability to compare SuDS designs with conventional designs in an ‘equivalent and fair manner’. Most international research indicates that SuDS are at minimum a financially better approach to urban drainage. Using a standard LCCA to consider the economics of different approaches is problematic, as it does not account for the water quality and quantity management that SuDS offers which conventional systems do not.

Conventional approaches to stormwater management expose the environment to potential degradation. Ignoring this will result in a biased comparison.

The literature review has highlighted that much of this research has failed to consider the environmental costs and benefits of the different approaches to stormwater management. The literature review has highlighted one model (Green Values Stormwater Tool) available in the USA that did highlight these aspects failed to appropriately appraise the costs and benefits, and to present results in a manner both useful and accessible to all stakeholders. Ignoring and / or failing to consider these costs and benefits, will result in a biased comparison. Recognition of this omission underpins the need for a model that incorporates the value of EGS. The reasons why these models have failed to consider the EGS include, but are not limited to the following:

- Minneapolis, City of Orlando and other cities internationally (City of Orlando, 2010; Minneapolis, 2010), have established stormwater utilities which have set charges based on resource requirements to maintain runoff quantity and quality. Rebates dependent on the system's design and its management of runoff are often included. The cost of the rates and rebates could be included into any study should a developer desire to consider these costs;
- Goods and services provided by the environment are taken for granted and not considered; and
- Measuring these costs is assumed to be difficult and / or of no concern to designers.

Table 2-17: Factors consider in deciding the need for a new model

Factor	Motivation
Cost estimation	Data in international studies is in some cases trapped in equations applicable to the country of origin. While based on historical data, there is seldom any explanation or background data available, and hence uncertainty of whether the use of such equations is valid.
Developed vs. the Developing world	The Literature Review showed that the cost of labour in the developed world is far higher than that in South Africa, while the relative cost of technology is generally lower. This creates a number of difficulties when trying to adjust formulae and data to South African values.
Exchange rates	Exchange rates fluctuate continuously and it is possible to obtain the data of these fluctuations. This data would be very inaccurate since factors such as those mentioned above are not dealt with by merely converting between currencies.
Scale of the model	Each of the available models is tailored to a certain scale. For Example MUSIC take a regional approach, whereas WERF spread sheets allow for the analysis of individual SuDS in isolation. It may be possible to combine the results from WERF spread sheets, however this would require further calculations which may not be possible for all those whom the model is intended for in South Africa. While it would be possible to consider individual SuDS options using Music, the program is designed for considering SuDS Systems. This is especially useful when comparing options for a specific role but makes considering a developments life cycle costs complicated. Ideally a model should allow for both of these.
Valuation of Environmental Goods &	The valuation of Environmental Goods and Services has not been considered in international studies. The only model which exists is inappropriate as it fails to

Services	consider costs and benefits of an 'fair basis'
Available software	Two software packages are available for analysing the Life Cycle Costs of SuDS. Both these packages consider conceptual designs. While conceptual designs might be acceptable when considering SuDS in isolation, or where the Conventional and SuDS designs are both conceptual, this is acceptable. It is not appropriate to consider the predicted costs of a conceptual design with those of detailed design. The case studies for this research are based on implemented projects it was felt that neither of these models would be useful.
Target user group	The target user group includes ALL professions involved in SuDS. This is an extensive list and includes technical and non-technical professions. Certain professions will have experience of economic analyses others will not. Therefore the model needs to be simple and require the minimum if any calculations from users.

After evaluating a number of software packages/ models it was felt that none of these could, for the following reasons be relied upon to give reasonable results for South Africa as:

- The historical data required to calibrate the inputs is not available.
- The models did not simultaneously consider both conventional systems and SuDS using the same approach, something that is vital for a "fair comparative study".
- The studies did not consider EGS.
- Certain models failed to account for the life cycles of the SuDS options (e.g. Lampe *et al.*, 2005).

The models therefore did not meet the requirements of the target user group.

3. Method Statement

The research went through three distinct stages: knowledge building; the development of a simple economic model that might be applied to a variety of sites within South Africa; and the application of this model to a number of sites, of different sizes and characteristics.

3.1 Stage 1: Knowledge building

The knowledge building undertaken comprised not only a traditional literature review that looked at relevant literature on a number of interrelated topics, but also included completing a number of courses.

The relative lack of knowledge about SuDS in South Africa made it vital that credible external input was sought. Attendance and completion of the courses listed in Table 3-1 formed a vital part of knowledge building. Course 5 was especially useful as it provided insight into the international application of SuDS technologies and tested knowledge gained from the literature review against what a leading institution considers best practice.

Table 3-1: Knowledge building Courses

Number	Course	Institution
1	Sustainable Urban Systems	University of Cape Town
2	Integrated Urban Water Management	University of Cape Town
3	Developing Cities	University of Cape Town
4	Municipal Infrastructure Asset Management	University of Cape Town
5	SUDS Online @ Abertay: Concepts & Design Principles	University of Abertay, Scotland
6	SWMM & PCSWMM	Computational Hydraulics International

3.2 Stage 2: Development of the model

To consider the economics of alternative approaches to stormwater drainage systems it was necessary to put together a model appropriate for South Africa that could consider the whole drainage system. The development of the model was a two-stage process as illustrated in Figure 3-1. Stage 1 encompassed the collection and assimilation of all the data necessary to perform a life cycle costing analysis. The data was assimilated and written up as the 'Fact Sheets' that form Appendix F of the proposed South African SuDS Guidelines. Stage 2 comprised the development of an Excel-based model capable of undertaking economic life cycle analyses.

3.2.1 Data collection

In order to be able to undertake a complete analysis over the whole life cycle of a system or compare systems it was necessary to collect basic data including:

- Capital costs;
- Maintenance costs;
- Maintenance frequencies;
- Disposal costs; and
- Expected Useful Lives.

There is very limited experience with respect to SuDS in South Africa, and the few organisations that do have experience appear to feel that divulging this information is potentially a threat to their organisation. By sharing institutional knowledge and experience, there is a risk of losing the organisation's competitive edge.

A number of firms including: contractors, consultants, quantity surveyors, landscaping, nurseries and garden services were contacted in connection with typical rates for construction. Most were unable or unwilling to be of assistance. A number of builder's pricing manuals were identified, however these were out of date or later found to contain restrictions on distributing the data. Subsequently the Department of Local and Co-operative Governance's Municipal Infrastructure Grant (MIG) manuals were identified and found to contain detailed unit rates for a wide variety of tasks. Making use of the Contract Price Adjustment Formulae (CPAF) these prices were adjusted to October 2010.

After considering the problem of identifying which sources' rates were most applicable, it was decided that by consistently using one source, the results overall would be reasonable. For this reason, the rates in the MIG manual were compared with those from all available sources, and unless deemed unreasonable, were used. Where they were deemed unreasonable the rates from the next most available and reliable source was used.

The same problem applied to identifying typical maintenance rates. The City of Cape Town undertook a survey into the costs of maintenance for their systems. This was updated using CPAF and CPI where appropriate. Where information was a missing further source were sought and in some cases international literature was used.

Identifying typical frequencies for maintenance tasks proved troublesome, and there is little evidence as to how the frequencies proposed in many manuals were determined. This is further complicated by the lack of experience with SuDS in South Africa. Lampe *et al* (2005) was identified as the most reliable source of maintenance frequencies for the following reasons:

- It sought to determine maintenance requirements based on experience, not judgements or estimates;
- It covered a wide variety of climates (both UK and USA); and

- It was developed through an international project combining the experiences and knowledge of some of the top drainage experts in the world.

Surprisingly, Lampe *et al* (2005) fail to identify the Expected Useful Lives (EUL) of the different technologies and simply compared all technologies over 50 years. While expert judgment may indicate many SuDS options could last this long, this is seldom the case. For this reason EUL's were identified from a variety of sources as shown in Table 2-7.

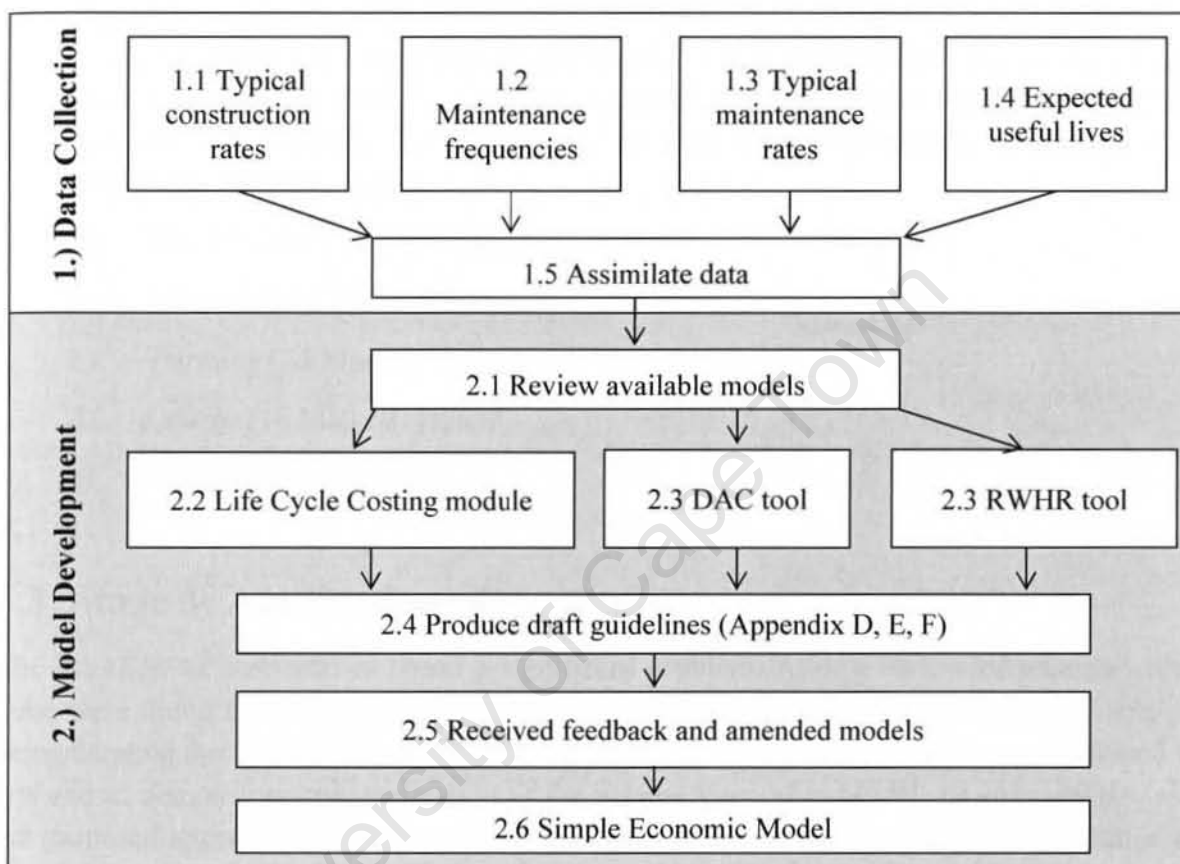


Figure 3-1: Overview of the models development

All of the above data was collected and compiled into a number of fact sheets that form Appendix F of the proposed South African SuDS Guidelines. It is important to stress that the data presented in these 'fact sheets' is meant as a guide, and an initial starting point from which to begin. Where better data is available on a site or as experience grows in South Africa, the latest information should be used.

3.2.2 Model Development

The model that has been developed is termed the Simple Economic Model (SEM). The developmental stages were as follows:

- i) The weaknesses and omissions in the studies reviewed in the literature review were identified, specifically:
 - a) The failure to account for Environmental Goods and Services on a fair and an equitable manner;
 - b) The absence of capability to consider more than one SuDS option; and
 - c) The failure to identify the Expected Useful Lives (EUL) of different technologies.
- ii) The SEM and background information was compiled and formed Appendices D, E, F of the proposed SA User Friendly Guidelines. These Guidelines were presented at a number of National workshops. During these workshops feedback was encouraged and received. The feedback was incorporated into the SEM. The national workshops were held in the following cities:
 - a) City of Cape Town (10 March 2011);
 - b) Johannesburg (23 March 2011);
 - c) Tshwane (24 March 2011);
 - d) George (16 May 2011); and
 - e) eThekweni (25 May 2011).

3.3 Stage 3: Application of the model

The selection of case studies posed a significant problem. After a review of potential sites none were found to be ideal for an economic analysis. It was therefore decided to focus on demonstrating the potential capabilities of the SEM. The following examples were selected to test and to demonstrate the application of the Simple Economic Model, its components, and the proposed appropriate procedure for undertaking such studies. They also cover a range of situations (different scales) and motivate how the ecosystem goods and services were modelled. The following examples were selected to demonstrate the range of capabilities of the SEM.:

- i) Residential House: Rainwater Harvesting & Reuse
 - a) Single SuDS option
 - b) Rainwater Harvesting & Reuse tool, DAC tool – only considering WQv storm, excluding land value
- ii) Large paved public open space – Grand Parade
 - a) Design Comparison, DAC tool – considering WQv storm, including land value
- iii) Commercial development – Mitchell’s Plain District Hospital
 - a) Multiple technologies/SuDS options, design comparison
 - b) ‘Cost’ Treatment Train

4. Simple Economic Model

4.1 Introduction

The wide range of environmental and economic conditions found in South Africa present specific challenges for the control and treatment of stormwater. To make informed decisions regarding the pros and cons of alternative designs for stormwater management requires a model that is able to compare SuDS designs with the conventional designs that have been the norm until now. The use of standard LCCA, for example, to compare a conventional design with a SuDS design is particularly problematic, as it does not account for the water quality and quantity management that SuDS offers. The risk of environmental degradation associated with conventional approaches to stormwater management has to be compared with the potential for water quality and quantity management offered by SuDS. To achieve this, a model that is unbiased, yet simple and accessible to all stakeholders in South Africa is needed. To this end, an Excel-based Simple Economic Model (SEM) was developed to address the weaknesses that were identified and attributed to the other available models. The SEM has four primary aims:

- i) To establish the life cycle costs of alternative drainage designs;
- ii) To account for the differences in environmental impacts on an 'equivalent and fair basis';
- iii) To provide a simple method that may be applied to different sites within South Africa; and
- iv) To present results in a manner that is accessible and understandable to the stakeholders, ensuring that all stakeholders have an understanding of what they are responsible for, and how much it may cost over the life cycle.

The SEM offers a tool for undertaking LCCA, thereby encouraging all involved with the provision of services to consider the whole life cycle of infrastructure.

4.1.1 Composition of the model

The model is, at its most basic, a Life Cycle Costing model that allows for the entry of data relating to EGS. The SEM further includes a tool to estimate the value of EGS using the Substitute Cost Method. This tool has been termed the DAC.

Due to a lack of local data and the large variation of social, economic and environmental factors across South Africa, the model contains assumptions relating to costs and maintenance frequencies. These assumptions are not inputted into the Excel based model but instead 'Fact Sheets' are supplied that may be used as guidance, or a starting point. Where accurate local data is available this should be used in place of the 'Fact Sheets'.

4.1.2 Accounting for Environmental Goods & Services

The ability to account for EGS is the most significant feature of the SEM as it allows for SuDS and Conventional Stormwater Management Systems to be fairly compared. The DAC tool provides a quick, conceptual estimate of the EGS on a regional basis. This tool applies the 'Substitute Cost Principle' in valuing the EGS in the form of the quantity management and quality treatment supplied by SuDS system. The assumption is made that conventional systems externalize the equivalent value, in the form of EGS, onto the environment at large. The value of the goods and services supplied by SuDS is calculated by considering the cost of acquiring and managing a virtual treatment facility that would produce equivalent quality treatment and quantity management of stormwater.

4.1.3 Conclusion

Utilizing the Simple Economic Model requires minimal understanding of economics or of engineering. The graphic presentation of results makes it accessible to wide range of stakeholders. As reliable local data is collected and recorded, the model can be updated to include a database. In the interim 'Fact Sheets' offering guidance have been supplied.

4.2 Aims of the Simple Economic Model (SEM)

The Simple Economic Model (SEM) was developed to address the weaknesses and omissions identified during review of the available models for undertaking economic analyses. The SEM has four primary aims:

- i) To establish the life cycle costs of alternative drainage designs;
- ii) To account for the differences in environmental impacts on an 'equivalent and fair basis';
- iii) To provide a simple method that may be applied to different sites within South Africa; and
- iv) To present results in a manner that is accessible and understandable to the stakeholders, ensuring that all stakeholders have an understanding of what they are responsible for, and how much it may cost over the life cycle.

Table 4-1 highlights 'requirements' for the SEM that need to be met for the 'aims' to be successfully achieved. These requirements are based on the outputs of the literature that identified potential requirements of such a model.

The four aims above are very broad. As already stated, the SEM presented above is not entirely new. In essence, it is a Life Cycle Model which has been integrated with two tools (DAC tool and Rainwater harvesting and reuse tool) for calculating the value of Environmental Goods and Services. What is important is how the model is applied.

Table 4-1: Aims of the Simple Economic Model

Aim	Requirements
Establish the life cycle costs of alternative drainage designs.	Calculate LCC for SuDS and Conventional Systems using the same approach making allowance for the differences in each system. Additionally allow the model to consider designs that incorporate both SuDS and Conventional design aspects, so called 'transitional systems.
	Allow for the aggregation and disaggregation of results, in line with SuDS principles i.e. for each level of the treatment train.
	Allow for the entering of different maintenance scenarios, and sensitivity analysis using the different scenarios.
	Allow for sensitivity analysis by varying the discount rate (impacts on EGS when using the substitute cost method).
Account for the differences in environmental impacts on an 'equivalent and fair basis.'	Provide a method for estimating the value of Environmental Goods & Services that may be used throughout South Africa.
	Account for the different life cycles of different drainage technologies.
	Allow for including additional benefits/costs for example appreciation of property values.
Provide a simple method that may be applied to different sites within South Africa.	Provide a model that is user friendly, and could be used by stakeholders with different competencies
	Provide all basic data (costs, maintenance frequencies etc.) to allow users to be able to conduct quick analyses.
	Provide a model that may be used on projects of different scales.
Present results in a manner that is accessible and understandable to the stakeholders.	Allow for the aggregation and disaggregation of costing data, in line with SuDS principles to allow users at different scales to identify the costs attributable to them.
	Present results in both detailed tables and simplified but accessible graphics.
	May be used in the design or management of SuDS.

4.3 Approach to Comparative studies

In essence, a Life Cycle Model has been integrated with a tool (DAC tool) for calculating the value of Environmental Goods and Services. What is important is how the model is applied. This section presents the approach that should be undertaken in conjunction with the SEM to conduct a comparative study on the economics of different drainage systems.

4.3.1 Introduction

A life cycle costing analysis (LCCA) is an appropriate analysis for considering and / or comparing the costs of stormwater systems. LCCA are used internationally to consider all expenditure over the system's life cycle. It ensures that all stakeholders have a conceptual understanding of their total commitments. It is important to recognize that there are a number of non-monetary benefits to SuDS as is discussed in Section 4.4.5. These may be accounted for in the SEM using the Damage Avoidance Cost tool detailed in Section 4.7, or any other appropriate method.

The SEM is based on macro-enabled Excel spreadsheets that can consider more than twelve SuDS options or conventional technologies. For each technology the SEM considers the following:

- the total capital cost per technology / component including establishment costs for up to the first three years;
- the inspection costs; and
- routine maintenance costs, irregular and corrective maintenance costs.

In line with Lampe *et al.* (2005), the study that was used to estimate the frequency of different tasks due to the lack of local data, it is possible to enter data for three different maintenance scenarios. Additionally, and critically in the case of conventional systems, the value of Environmental Goods and Services (EGS) are accounted for through using a 'Damage Avoidance Cost (DAC)' tool. The DAC tool is an estimate of the minimum cost of treating the stormwater discharge to the receiving waters to a level equivalent to that provided by SuDS through the device of a virtual stormwater treatment works. The treatment works does not exist, it is merely a means to estimate the value of EGS expected from the receiving waters.

The SEM can analyse stormwater management systems over any period up to a maximum of 100 years, although shorter analysis periods are generally more appropriate. The program ensures that the maintenance schedule is 'reset' when a technology/component is replaced. With the aid of this SEM it is possible to quickly and fairly complete a comparative analysis of two very different drainage systems. The output of the SEM is a number of user-friendly comparative charts and tables.

4.3.2 Computational stages in the SEM

The model has three distinct computational stages as indicated in Figure 4-1. The model may be applied in a number of ways:

- To compare a SuDS and a conventional design;
- To compare two SuDS designs (in which case Step 2a may be omitted); and
- To consider the costs and benefits of a single SuDS design (in which case Step 2b may also be omitted resulting in a standard LCCA).

4.3.3 Stage 1 – Life Cycle Cost appraisal:

A design for the site is developed. All costs over a common life cycle are reduced to their present value. The life cycle analysis considers different maintenance regimes, i.e. High, Medium and Low maintenance for both SuDS and conventional designs, as different maintenance regimes may result in different outcomes. The Fact Sheets may be used to estimate these outcomes. It is important to recognize that different drainage systems cannot

be compared at component level. A green roof cannot for example be directly compared with a conduit that would convey an equivalent roofs runoff to the municipal storm sewer as the value of the municipal storm sewer would also need to be considered. Proposals need to be considered as whole systems where possible and not as individual components.

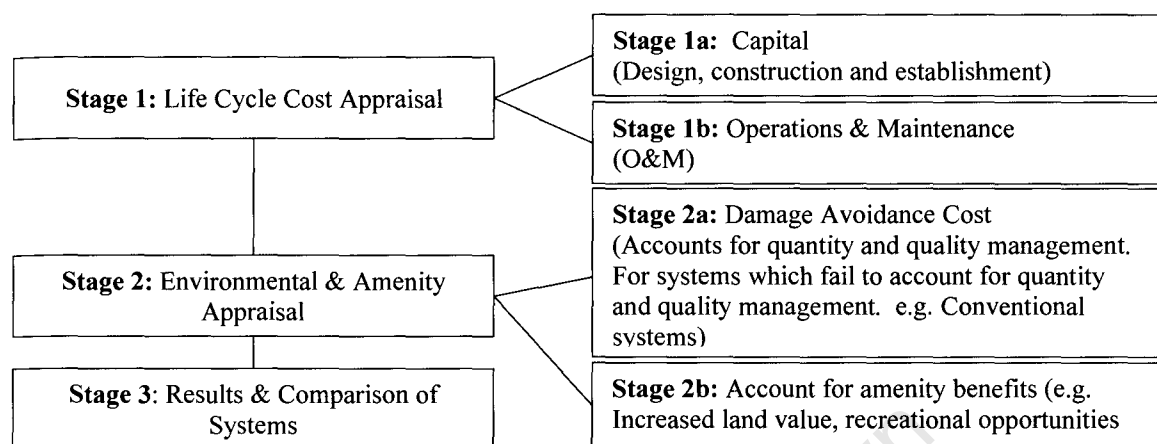


Figure 4-1: Computational stages in the SEM

4.3.4 Stage 2 – Environmental & amenity appraisal:

Where Stage 1 provides LCCAs of the monetary aspects, Stage 2 considers the non-monetary aspects. For comparison with conventional systems the EGS supplied by SuDS, but not conventional systems, need to be considered. The EGS are valued using the DAC tool. The DAC tool calculates an annual environmental cost to substitute for the fact that the environment is continuously treating and managing runoff from conventional systems. The SEM then reduces the costs to their present value. One shortcoming is that SuDS cater for water quality, quantity and amenity whilst the DAC tool only considers water quality and quantity. Where local data is available for the valuation of the amenity this can be entered into the model. All systems are now being considered on a reasonably 'fair and equivalent basis'.

4.3.5 Stage 3 – Results and comparison of systems:

The process outlined in Figure 4-1 should be completed for each proposed design, ensuring that all designs are developed to manage the same design storm. The SEM aims to compare the systems in a transparent manner and thus the different cost elements are presented separately, as indicated in Table 4-2. This also allows for a comparison of the two systems from a number of different perspectives *viz.* the capital costs that are of particular interest for developers, the environmental costs that are of particular interest for environmentalists and the maintenance costs that are of particular interest for the property owners. Sensitivity analyses may also be undertaken, for example by varying the discount rate and/or level of maintenance.

Table 4-2: Comparing a SuDS system with a conventional system

Stage	Item	Proposal 1 (e.g. SuDS)	Proposal 2 (e.g. Conventional)
1	A	Capital Costs	R XXXX,XX
	B	O&M (PV)	R XXXX,XX
		Sub Total 1	R XXXX,XX
2	A	Quantity & Quality management (Damage Avoidance Cost) (PV)	R 0,00 (meets set criteria therefore no externalized environmental costs)
	b	Amenity (local / site specific data) (PV)	R XXXX,XX
		Total "Cost" (PV)	R XXXX,XX

When considering results it is important to recognize that: *"the question is not whether stormwater management system maintenance is necessary in a community. Rather, the question is how a community's maintenance programs will be budgeted, staffed, and administered, and who has responsibility for managing inspections, scheduling periodic required maintenance, and funding remedial work (Haubner et al. 2001)."*

To consider simply the sub-totals and totals is not acceptable. It is vital to identify and to consider:

- Who will be responsible?
- Who will pay?
- That savings are not made on capital expenditure resulting in higher long term maintenance burdens.
- Whether the design considers the whole life cycle?

Table 4-2 is useful in identifying where the largest burden lies i.e. whether it is environmental, maintenance or capital expenditure. It does not identify who is responsible for paying for capital and maintenance costs. It would therefore be possible to present a plan that transferred the burden of costs over the life cycle onto the municipality. In order to ensure that this cannot be unknowingly done, the SuDS 'Costs' Treatment Train was assembled as shown in Figure 4-2. By viewing the results using the SuDS 'Costs' Treatment Train it is clear who pays, and indirectly who is responsible for what amount of maintenance. It also makes it clear whether the burden has been unfairly cast at one level.

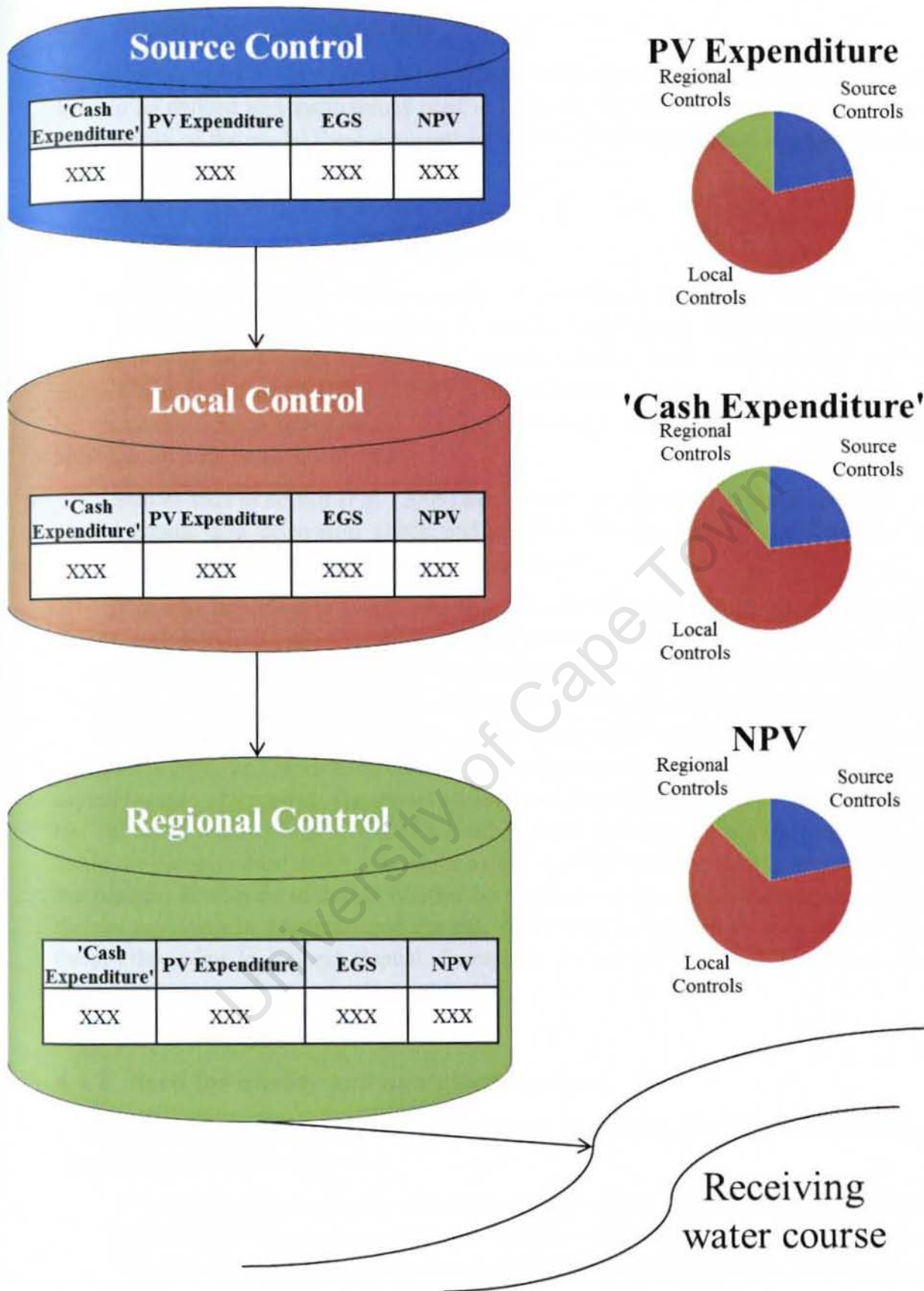


Figure 4-2: SuDS 'Cost' Treatment Train

4.4 Modelling Assumptions

To model two very different systems in a fair and transparent manner, a number of aspects need to be defined and assumptions need to be made. To ensure transparency, fairness and the integrity of the model these assumptions and the motivation behind the assumptions are discussed in this section.

4.4.1 Definition of an 'economic' model

An economic model implies a model capable of considering all monetary and non-monetary costs and benefits. Clearly, it would not be possible to develop a model that would consider all the non-monetary costs for any site in South Africa. New developments, and many redevelopments fall under NEMA (2006) which requires an environmental impact study to be undertaken. Thus many social, environmental and economic factors are considered, although not necessarily quantified.

Studies such as de Wit *et al.* (2009) have gone to great lengths to assess the value of the natural capital and ecosystem goods and services. Studies such as this consider many different aspects not related to stormwater management.

It is also important to clarify the difference between Natural Assets and Ecosystem Goods and Services. de Wit *et al.* (2009) states: "*Natural assets are the stocks of environmental resources.... Ecosystem goods and services are the flows of benefits derived from these assets*". Ecosystem goods and services could therefore be considered equivalent to interest on invested capital. Thus the fewer assets you have the less interest earned (ecosystem goods and services received). This study is not directly concerned with the natural capital balance of a project. The model assumes that the designer ensures that runoff entering into the urban watercourses is of such a standard that it does not degrade the ecosystem. In so doing the designer must select into which capital account he/she wishes to invest. In essence the designer is allowed to decide whether he wishes to make use of technological solutions thereby investing in Manufactured Capital; or whether he wishes to make use of SuDS, thereby investing in Natural Capital. Essentially the model indirectly allows the user to consider alternative "investment" solutions.

4.4.2 Need for quality and quantity treatment

In a country that is water scarce, the arguments in support of stormwater treatment are indisputable as discussed below:

- i) In a country such as South Africa that is water scarce, water should be considered a resource. The literature review shows that there is potential for accessing groundwater resources and for utilizing untreated runoff for secondary systems such as flushing toilets etc. This potential resource will be lost if the runoff is too polluted or the aquifers are not replenished.

- ii) Natural resources and the goods and services they supply are valuable to society – even if this value is seldom recognized or appreciated. Polluted and unmanaged stormwater has the potential to decrease the value of these resources. These assets support many industries including fisheries and tourism, while also providing society with recreational areas. Failure to manage stormwater effectively will lead to the continued degradation of these resources. A point will be reached where in many cases the environment is unable to offer these goods and services. Studies that considered the economic effect of the failure of systems found it to be significant.
- iii) As natural treatment facilities such as wetlands degrade, less and less runoff is adequately treated. The literature review highlighted that many urban rivers are polluted, a common problem throughout South Africa, which may be partially attributed to stormwater quality and has potential public health impacts.

Throughout South Africa, there is an ethical responsibility to acknowledge that many services with respect to stormwater are currently externalized onto the environment. With the potential impacts on many sectors of the economy, it is considered reasonable to require treatment for stormwater. The literature review also highlighted the legal liability of the polluter to pay for any pollution. If stormwater treatment is not provided, the environment is susceptible to degradation. It is therefore vital that stormwater be treated from both a quantity and a quality perspective and that these costs are borne by the polluter and not society at large.

4.4.3 Design parameters

For the purpose of this model, it is assumed that both SuDS and conventional designs will be based on the principles set out in Table 4-3. This will ensure that the designs are comparable.

Table 4-4 details specific minimum criteria that each design must meet. These criteria are based on the CoCT's Management of Urban Stormwater Impacts policy 2009 (CSRM, 2009). These parameters are achievable using both SuDS and conventional treatment systems and thus allow a fair comparison to be made.

Table 4-3: Minimum Design Parameters

	Parameter	Description
1	Design Storm	Designs to be based on the same recurrence interval storm.
2	Quantity Management	Meet the criteria set in the City of Cape Town's "Management of Urban Stormwater Impacts" policy document (CSRM, 2009).
3	Quality Management	Meet the criteria set in the City of Cape Town's "Management of Urban Stormwater Impacts" policy document (CSRM, 2009).
4	Damage Avoidance Cost	Where either design fails to meet any of the above.
5	Life Cycle Period	The life cycle analysis will be conducted over the period for which both designs' Life Cycles have the lowest denominator.

Table 4-4: City of Cape Town Stormwater Management Policy criteria (CSRM, 2009)

Objectives	Pollutant	Modelling Parameters
Quantity Control	Increased Peak Flows	Management of the Quantity Control volume (QCv) storm.
Quality of run-off	Litter/Debris	Complete Removal
	SS	80% reduction
	TP	45% reduction

4.4.4 Discount Rate

The SEM has been set up to allow the user to vary the discount rate to be appropriate for the specific project and for sensitivity analyses.

4.4.5 Accounting for Ecosystem Goods and Services

The valuation of EGS is the most significant feature of the SEM as it allows for SuDS and conventional stormwater management systems to be fairly compared. In order to value EGS the Damage Avoidance Cost (DAC) tool was developed. The DAC tool provides a quick, conceptual estimate of the EGS. This tool applies the 'Substitute Cost Principle' for valuing the EGS in the form of the quantity management and quality treatment supplied by SuDS system. The assumption is then made that conventional systems externalize the equivalent value, in the form of EGS, onto the environment at large. The value of the goods and services supplied by SuDS is calculated by considering the cost of acquiring and managing a virtual treatment facility that would produce equivalent water quality treatment and quantity management. Typical treatment objectives considered achievable by the City of Cape Town (2009) for SuDS are presented in Table 4 4. The DAC is discussed in detail in Section 4.7.

A common criticism of the replacement/substitute cost method is that it over estimates the value of EGS. In certain cases, this may well be true. While it is possible to show that the resource/cost could be 'valued as less', this is sometimes 'proved' by ignoring certain goods or services. This section highlights two such examples, and motivates the appropriateness of this method for this model.

Pagiola *et al.* (2004) highlights a case study where New York City investigated the costs of the value of replacing the ecosystem services with respect to water quality. This investigation considered the use of a filtration plant to treat the water. The City found these costs to be "expensive". *"To avoid incurring this cost, the City embarked on an alternative approach: instead of paying to clean up the results of degrading the water producing environment, the City invested in preserving the rural Catskill environment that was providing it with the world's best urban water (Pagiola et al., 2004)."* This second approach resulted in a much lower cost as indicated in Figure 4-3.

Pagiola *et al.* (2004) concludes by stating: *"This example also illustrates the perils of the replacement cost technique. Clearly, the filtering was not the least-cost solution to the*

problem! Using it to value the filtration services provided by the watershed would have been a massive over-estimate.” Financially this may be true, but Pagiola *et al.* (2004), have failed to consider the value of the goods and services provided by the environment. Pagiola *et al.* (2004) acknowledge that should the environmental services have been lost, the City would have had little choice but to implement the filtration option. Instead, the City made a paradigm shift, recognizing the value of and investing in the environment, thereby maintaining the natural capital and associated goods and services. This ensured that the environment could continue offering these services at no financial cost to the city. Provision of services without financial outlay does not equate to valueless services. The paradigm shift was informed by recognizing what investments would be needed to take a conventional/technical approach. The conclusion regarding “the perils” of the replacement cost method is based on a financial appraisal and not an economic appraisal.

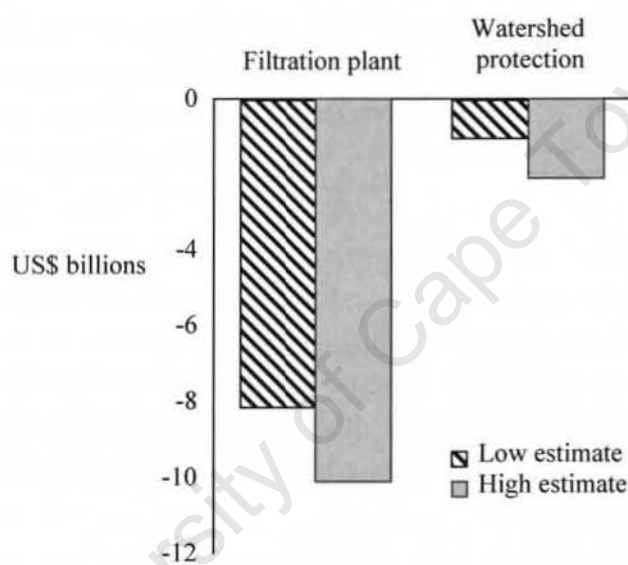


Figure 4-3: Costs of Alternative strategies to meet New York City water quality requirements (Pagiola *et al.*, 2004)

De Wit *et al.* (2009) highlight a study by Turpie (2001) that estimated the value of the Zandvlei wetlands. It was based on three replacement cost estimates:

- *“Estimation of the cost of constructing an artificial wetland*
- *Estimation of the cost of providing the same level of water quality enhancement using a treatment plant*
- *Estimation of the cost of providing for the identified flood storage capacity only, i.e. the construction of a detention pond providing flood storage”*

For Zandvlei the replacement cost for water quality treatment was estimated at a total of R180 million (R15 million annually) and the replacement cost of flood storage capacity at R24 million (R2 million annually). This cannot be a true reflection of the cost as the system provides both quantity and quality treatment. In determining the value of the cost of replacing both the quantity and the quality has to be considered, a total cost of R204 million.

R204 million is a significant amount for a single wetland, but as De Wit *et al* (2009) state “*Several of these services may save cities significant amounts in terms of infrastructural costs which they would have had to incur if the natural systems were not present (de Wit et al., 2009).*”

The values are large, especially in respect of resources vital to society; there is therefore a need to consider the context of the results before dismissing them. Pagiola *et al.* (2004) suggest that the results be submitted to the sanity check that considers whether “*the results are consistent with other results? Are they reasonable in light of the context? Extraordinary results are not necessarily wrong, but must be carefully checked. Extraordinary results require extraordinary proof (Pagiola et al., 2004).*” Most important is the acknowledgement that “*Extraordinary results are not necessarily wrong...*”. It is disingenuous to make comparisons on an ‘uneven playing field’. Purely financial appraisals may not lead to accurate conclusions.

The Replacement Cost Method is reasonable in this context. It meets the accepted ‘requirements’ for use as discussed above. The common criticism of the method, its perceived potential to overestimate the value of a resource, would be unfounded and management capabilities of such systems without accounting for the cost of the increased floods and the associated damage and health impacts of these floods. It would be fair to expect these costs to be a lot higher than simply managing the floods before they cause damage.

The method is also seen as appropriate for such situations “*open space and catchment managers could use this methodology to compare the annual management and operation costs with the replacement cost and value of these systems. Furthermore, this type of data could be used to motivate for resources to ensure that future engineering solutions will not be required to replace degraded natural systems no longer able to provide the required services to the CoCT*” (Smit & Wiseman, 2002).

4.5 Model Structure

It is important that the design process and the selection of alternative stormwater strategies be done in a fair manner. Section 4.3 lays out the procedure to undertake such an analysis using a ‘Simple Economic Model’ (SEM).

4.5.1 Overview

The Simple Economic Model (SEM) comprises in excess of 30 spreadsheets. It is designed to undertake calculations based on user inputs. Due to the lack of local expertise within this field, it was not seen to be appropriate to develop a model with data already built in. Rather, a set of 'Fact Sheets' were developed and are included as Appendices D - F. These appendices were released for review as part of the development of proposed guidelines for SuDS in South Africa. These appendices were developed to supply all the data required to utilize the SEM for both SuDS and conventional systems where local data and expertise were lacking.

4.5.2 'Fact Sheets'

Each fact sheet included contains a summary of the information required to conduct a preliminary 'life cycle costing' analysis for a stormwater drainage design using the SEM. The Fact Sheets serve as guidelines for the costs associated with different technologies, however site specific considerations need to be considered. An Example of a "Fact Sheet" is shown in Figure 4-4.

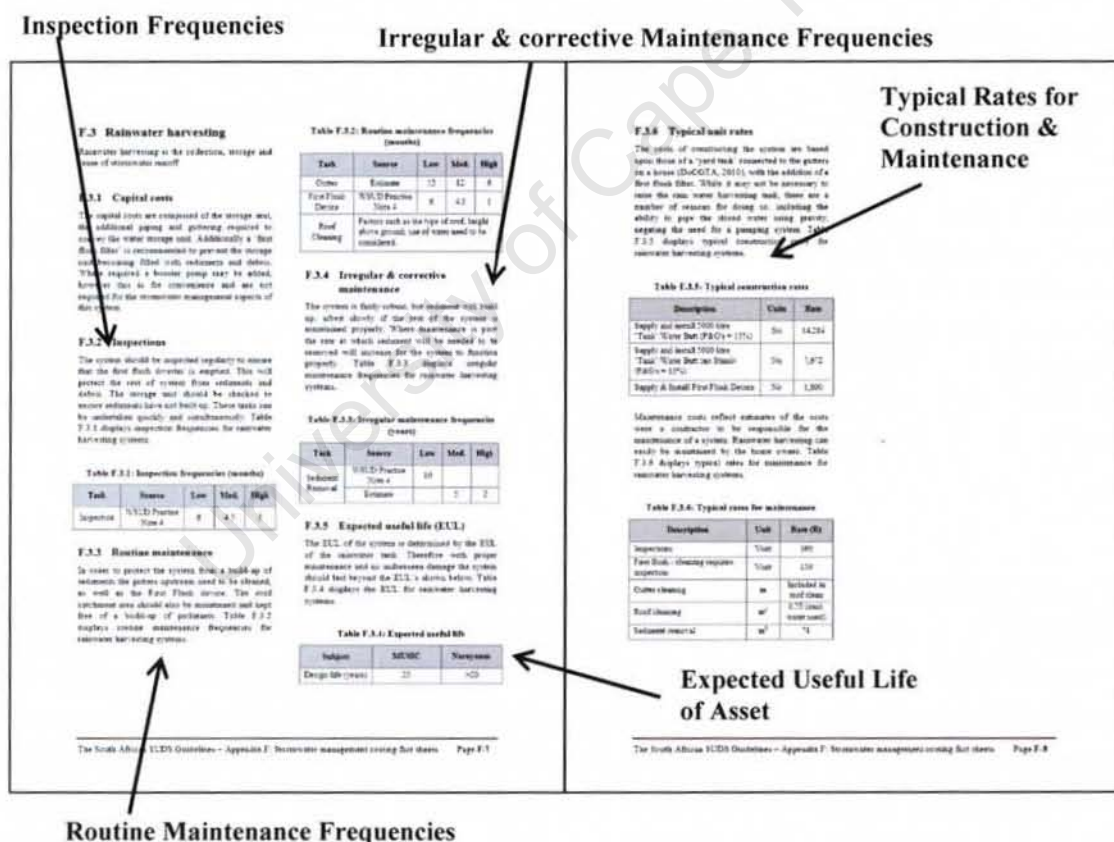


Figure 4-4: Sample 'Fact Sheet'

The information contained in each of these sections is shown in Figure 4-4. Conventional stormwater drainage systems are included as components of conventional systems are often used as part of a SuDS system. Additionally, it is important to objectively compare the costs of each system –SuDS vs. conventional systems. For this purpose a section detailing the costs relating to conventional systems has been included. Table 4-5 lists the available fact sheets corresponding to the twelve primary SuDS options included in the main text of the guidelines.

4.5.2.1 Summary of capital costs

The ‘capital costs’ section in the fact sheets details problems that have been experienced in implementing specific SuDS options and the impact on their capital costs. Typical unit rates for construction are also presented.

Table 4-5: Fact sheets SuDS options

Fact sheets	SuDS assessed
Conventional design	Inlets, outlets etc.
Rainwater harvesting	Rainwater harvesting
Infiltration Trenches / Soakaways	Infiltration trenches / soakaways
	Filter trenches
Green roofs	Green roofs
Bio-retention	Bio-retention
Grass swale	Swales (dry, wet, enhanced)
Permeable pavements	Permeable pavements
Buffer & filter strips	Buffer strips
	Filter strip
Dry stormwater ponds	Detention ponds (dry, enhanced)
Wetlands & wet Ponds	Wetlands
	Wet ponds

4.5.2.2 Summary of maintenance costs

The inspections, routine maintenance and corrective maintenance frequencies have been presented in the fact sheets are largely based on work done by Lampe *et al* (2005). The results are presented for the USA and UK separately, and are based on the USA format. It is worth noting that this study is available on the WERF website along with a set of MS Excel costing tools as noted in the Literature review. These frequencies reflect typical frequencies for individual SuDS. In reality, frequencies and associated costs will be dependent on a number of factors including land use, climate, treatment train, component design etc. In addition, typical ‘routine and corrective maintenance’ costs are presented. These have been sourced from builders pricing guides, discussions with members of industry, the CoCT and a range of recent tenders from across South Africa.

4.5.2.3 Predicted life cycle costs

Lampe *et al* (2005) failed to identify potential life cycles for individual SuDS – rather leaving this to be assessed individually. The Fact Sheets presents a number of Life Cycles as sourced from international literature. These should be applied after due consideration of the variations between local conditions and those found in the country of origin. Explanations of possible maintenance activities for each SuDS option are included in the Draft SuDS guidelines and were not included in these ‘Fact Sheets’.

4.5.2.4 Typical rates

The typical rates for capital costs presented in the fact sheets are estimates that are based on DoCGTA (2010) and recent tenders. These were checked against industry pricing manuals. It was decided that the Municipal Infrastructure Grant guidelines (DoCGTA, 2010) should guide the typical rates, as they are based on extensive research and stakeholder input. All rates exclude VAT, P&G's, and consulting/design fees. The typical rates presented for operations and maintenance has been collected from the municipality and firms within the City of Cape Town. It is important to recognize that these rates are an indication. Where more detailed information is available, it should be utilized. Identifying typical unit rates for landscaping is specifically difficult, as the contractors individually determine their rates. Additionally, the cost of vegetation varies significantly. Grass is a prime example. Buffalo grass cost more than R50 per square meter in 2010, whereas Kikuyu grass was typically less than half the cost at R20 a square meter. For swales and buffer strips, this could have major cost implications as grassing is a significant cost factor.

4.5.3 Recharge Maps

Currently the only authorities that require ground water recharge to be designed as part of a SuDS/LID/BMP design are in the USA - Maryland and Massachusetts (Stormwater Centre, 2011). These two authorities base their assumptions as to how much should be infiltrated on the SCS soil groups. There is insufficient research to verify the results locally. Therefore two approaches have been taken to offer guidance. The first is to assume that the USA soil classifications are comparable to the RSA SCS soil groups. The second makes use of DWA data relating to the recharge and runoff of Quaternary catchments.

4.5.3.1 USA SCS Soil Groups

The “*recharge factor (S) is based on the USDA (SCS) average annual recharge volume per soil type divided by the annual rainfall and multiplied by 90%. This keeps the recharge calculation in line with the WQv calculation methodology*” (Maryland , 2000).

As South Africa has a wide variety of climates, the recharge factors are given for a range of different Mean Annual Precipitation's (MAP) in Table 4-6. The accuracy and appropriateness of Table 4-6 for South Africa is unknown due to the slight variations in soil

classification used in the South African SCS model. The Recharge Maps (Figure 4-5) were developed from data supplied by the Department of Water Affairs to provide guidance based on local data.

Table 4-6: Recharge Factors (S) based on USDA (SCS) classifications

Hydrologic Soil Group	Average Annual Recharge Volume (mm/yr.)	Soil Specific Recharge Factors (S) for different MAP						
		100	200	300	400	500	600	700
A-Sandy	457	1	1	1	1	0.82	0.69	0.59
B-Silty	304	1	1	1	0.68	0.55	0.46	0.39
C-Clayey	152	1	0.68	0.46	0.34	0.27	0.23	0.2
D-Clayey	76	0.68	0.34	0.23	0.17	0.14	0.11	0.1

4.5.3.2 South Africa Quaternary Catchments

In this case S is based on the average annual recharge volume per quaternary catchment divided by the mean annual precipitation per quaternary catchment and multiplied by 90%. The Average Potential Dry Recharge (APDR) was divided by the Mean Annual Precipitation (MAP) and multiplied by 0.9. This keeps the recharge calculation in line with the WQv calculation methodology and with the method used by Maryland. The APDR was used as it *"is the most reliable and does not include what amount that can be taken from the aquifer's storage as this should remain as an aquifer reserve"* (Van Wyk, 2010). The data is old (2005) and there are potentially errors in it, and should therefore only be used as a guide. The 'Recharge Maps' provide the recharge factor as a percentage, as shown in Figure 4 5.

4.5.3.3 Calculating the recharge volume

The recharge volume may be calculated by hand by using Equation 2.

$$RE_v = WQ_v \times S \quad (2)$$

where: RE_v = Recharge Volume; WQ_v = Water Quality Volume; S = Recharge Factor.

For the purposes of the Damage Avoidance Cost tool, the tool undertakes this calculation, it is only necessary to specify the Recharge Factor (S) and WQ_v which would be specified by the local authority or be the volume of water managed for water quality treatment by the SuDS system.

Recharge Requirements -Major cities-

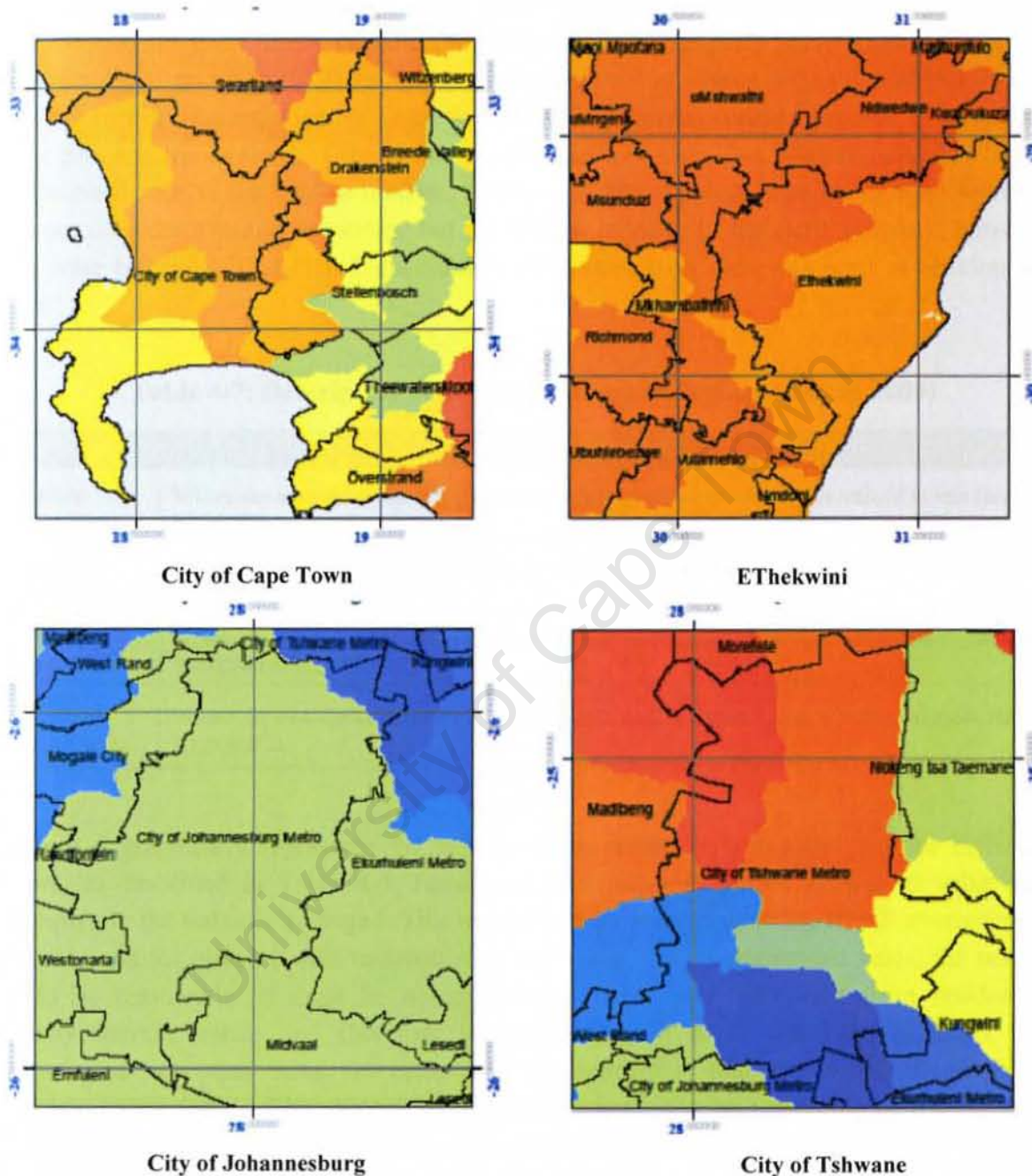


Figure 4-5: Recharge Maps for Major South African Cities (After DWEA, 2010)

4.5.4 Land Value Indicators

Where land is not available for use as a treatment facility, it may be appropriate to include the value of the land in an analysis of the DAC. In such a case, it would be necessary to identify the costs of undeveloped land in an equivalent area. To provide guidance as to the value of undeveloped land, the City of Cape Town's 2000 property valuation roll was analysed. The 2000 roll was the most recent valuation role released and a property value index was used to adjust the 2000 prices to 2010 values. The Index shown in Figure 4-6, and Table 4-7, was developed from data supplied by Light Stone (2011). Various sources claimed to have data on the property trends for the City of Cape Town. Light Stone's data was considered to be the most accurate due to the approach taken, which considers property re-sales. In other words it does not consider average properties, but the change in value of the same property, however none were better justified than Light Stone's data hence their data was used to develop the Index.

Table 4-7: Description of property value bands (Light Stone, 2009)

Category	Description
Affordable (South Africa)	Where the average value of a properties within an Enumerator Area is valued at less than R250,000.
Middle Value (South Africa)	Where the average value of a properties within an Enumerator Area is valued between R250,000 to R700,000.
High Value (South Africa)	Where the average value of a properties within an Enumerator Area is valued between R700,000 to R1,500,000.
Luxury Value (South Africa)	Where the average value of a properties within an Enumerator Area is valued at more than R1,500,000.

Figure 4-6 graphically represents the results of the index. It is evident that the different sectors, as described in Table 4-7, have seen different amounts of growth in value and consequently the index is averaged. This means that for some properties, it will overestimate the value and for others it will underestimate the value. On an aggregated basis, the results should be reasonable. It must be noted that this Index was developed from residential property market trends and therefore its application to non-residential properties and undeveloped land may result in error. The assumption is that prices will fluctuate in accordance with trends. The purpose of this section is to give an indication of the value of undeveloped properties. For detailed analysis it would be necessary to identify the value of undeveloped land in close proximity to the site in question.

The City of Cape Town's property valuation role was considered based on the different drainage catchments, as stormwater treated on a regional basis, would come from a range of developments. Based on the land value results for different drainage catchments, the values in Table 4-8 are proposed as guidelines to the value of undeveloped land as at October 2010. It will be necessary to calculate these values locally. The approach used above could be repeated.

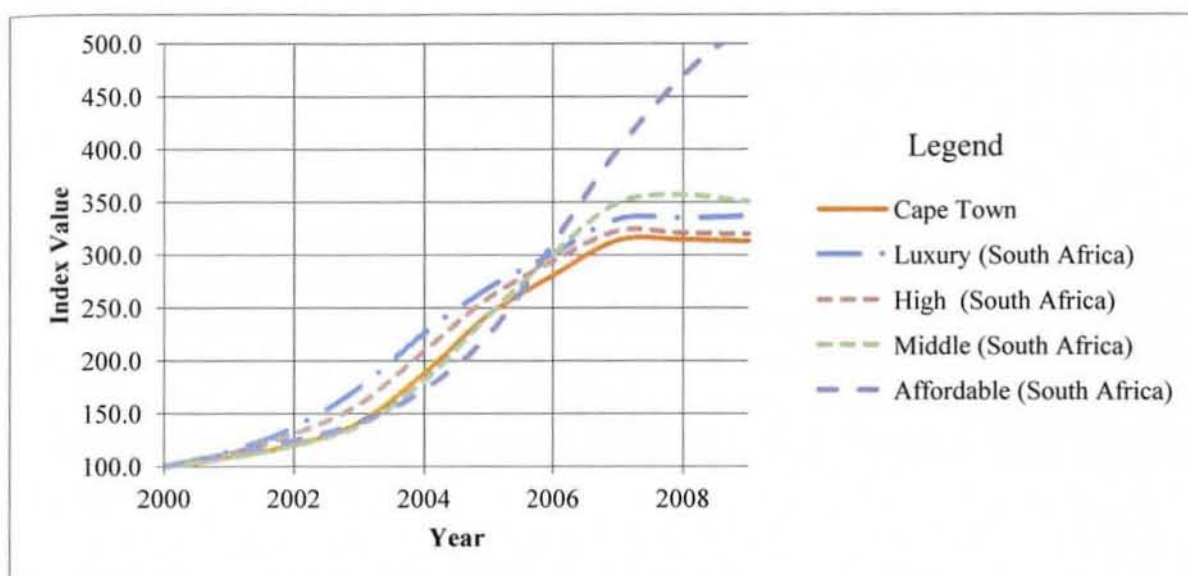


Figure 4-6: Shows the changes in the property market for the since 2000

Table 4-8: Land value for different income areas – Cape Town, 2010

Land Use	Land Value (R/m ²)
CBD – Commercial	1,550
High income catchments	2,230
Middle income catchments	1,260
Low income catchments	740

4.5.5 General SEM Structure

The structure of the Simple Economic Model is detailed in Figure 4-7. The SEM is comprised of the following four components:

- i) SuDS single component;
- ii) SuDS full system;
- iii) Conventional full system; and
- iv) Damage Avoidance Cost.

The components shown in Figure 4-7 together form the SEM and comprise of multiple individual spreadsheets, as illustrated in Figure 4-7.

4.5.5.1 SuDS Single Component

This Spreadsheet allows a user to consider a single technology and consider the costs and benefits over a life cycle.

4.5.5.2 SuDS Full System

The SuDS Full System comprises 12 individual spreadsheets that analyse individual SuDS options over a user specified analysis period. The analysis includes the ability to account for EGS costs or benefits associated with the specific SuDS. The User is able to specify whether each SuDS option is at Source, Local or Regional scale. Results are then available at each scale. The ability to view the costs at different scales is vital as different stakeholders have different interests. This is neatly summarized in the SuDS 'Cost' Treatment Train, as shown in Figure 4-2.

4.5.5.3 Conventional Full System

The Conventional Full System comprises a single spread sheet capable of considering up to ten different technologies.

4.5.5.4 Damage Avoidance Cost

The Damage avoidance cost sub-module comprises four spreadsheets.

- i) Spreadsheet 1 conducts a Life Cycle analysis as per the SuDS / Conventional system analyses;
- ii) Spreadsheets 2 is used to route the runoff for the Water Quality volume storm (WQv);
- iii) Spreadsheets 3 is used to route the runoff for Quantity Control volume storm (QCv); and
- iv) Spreadsheet 4 is used to set the design parameters for the analysis.

4.6 Structure of Economic Life Cycle Costing spreadsheet

The following section supplies a brief overview of the structure of the individual spreadsheets used to analyse technologies over a specified period. It is detailed in Figure 4-8 and the spreadsheet is designed around five modules:

- i) LCCA sub module
- ii) Irregular maintenance and replacement scheduler sub module
- iii) EGS sub module
- iv) Economic calculation module
- v) Results

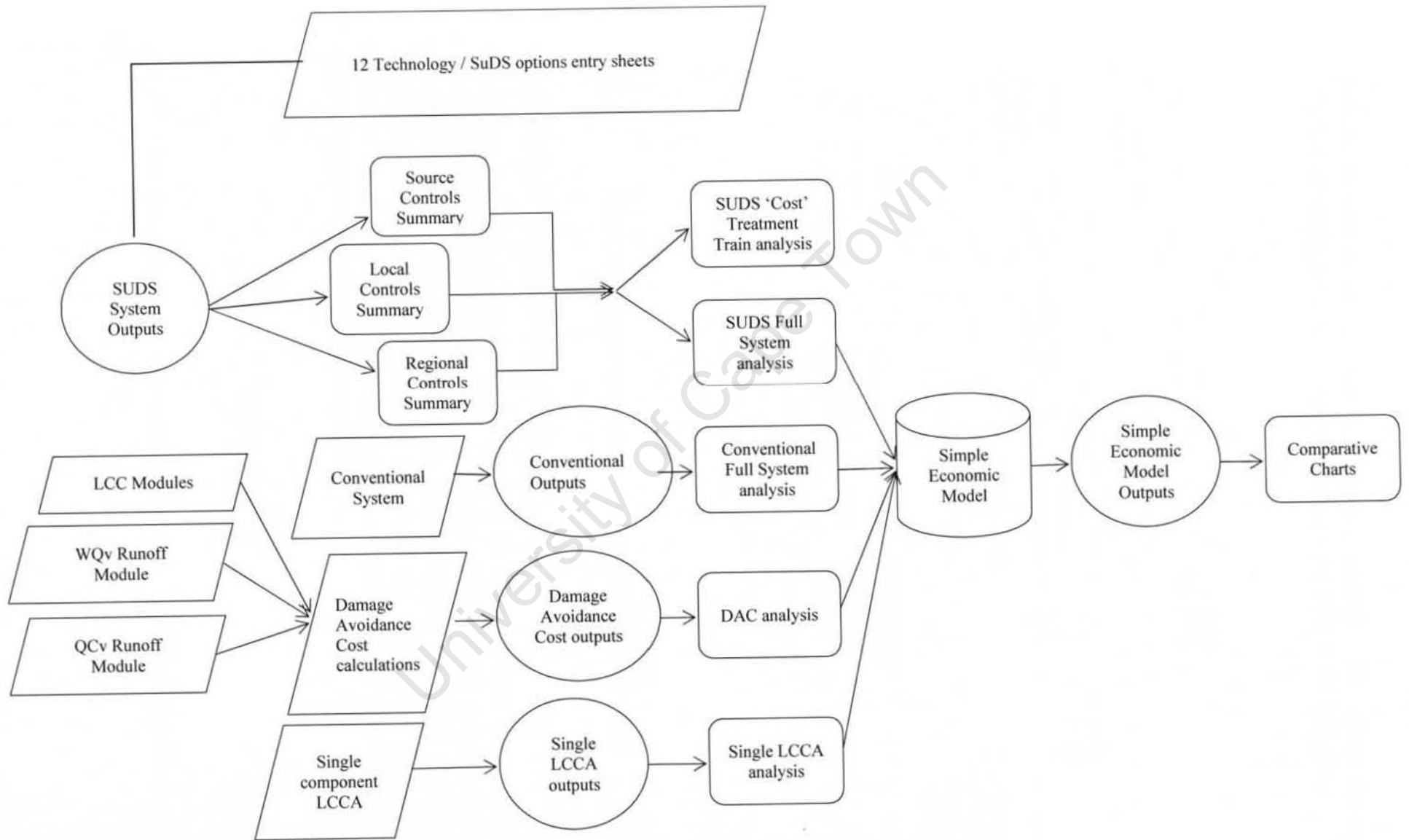


Figure 4-7 Structure of Simple Economic Model

4.6.2 LCCA sub module

The LCCA sub module simple calculates and enters the data related to capital costs, establishment costs, inspections costs, and routine maintenance (annual maintenance) directly into the Economic calculation module. The LCCA sub module calculates the annual "cash" cost for establishment; and for inspections and routine maintenance. These values are entered into Columns 3 and 4 of Table 4-10.

4.6.3 Sub Module for the scheduling of Irregular maintenance and replacement

To avoid irregular maintenance occurring in the same year or within an unreasonably short period after an asset was replaced the following sub module was put in place. The sub-module ensures that once the asset is renewed the maintenance cycle would be reset, and the costs recalculated. These results are then entered into the Economic calculation module. The 'scheduling of Irregular maintenance and replacement' sub module resets the irregular and corrective maintenance schedule when an asset is replaced. The module then schedules the maintenance at the specified recurrence intervals for each component. Should a component be replaced, the module restarts the schedule. For example, if paving requires a minor overhaul every 5 years and replacement every 10 years, the module will schedule the maintenance and replacement as shown in Table 4-9. Once the maintenance and replacements are scheduled a total cost for each year is calculated. These 'cash values' are entered into the Economic Calculation Module.

Table 4-9: Calculation of corrective and irregular maintenance

Age of System	Age of Component	Task
9	9	
10	10	Replace end of year
11	1	
12	2	
13	3	
14	4	
15	5	Irregular maintenance

4.6.4 EGS Sub Module

The EGS Sub Module allows the user to enter EGS as benefits or costs. This is then entered into the Economic Calculation Module.

Table 4-10: LCCA Summary Costing Module (for one maintenance scenario)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Year for Graphs	Discount Factor	Capital & Replacement Expenditure	Establishment Costs	Inspections & Regular Maintenance	Irregular and Corrective maintenance	Σ Cash' expenditure for Year SuDS	PV of Capital & Replacement Expenditure	PV of Year Establishment costs	PV of Irregular & Corrective Maintenance	PV of Years Costs - SuDS	Total Cash Expenditure' - SuDS	Σ Present Value Expenditure - SuDS	
0	1.0000	395000	0	0	0	395000	395000	0	0	395000	395000	395000	
1	0.9259	0	9600	10690	0	20290	0	8888	9898	18787	415290	413787	
2	0.8573	0	9600	10690	0	20290	0	8230	9165	17395	435580	431182	
3	0.7938	0	9600	10690	0	20290	0	7620	8486	16107	455870	447289	
4	0.7350	0		10690	0	10690	0		7857	7857	466560	455147	
5	0.6806	0		10690	8900	19590	0		7275	6057	486150	468479	

4.6.5 Results

For each SuDS option (family), or for Conventional Systems, results are presented for all three maintenance scenarios at the set discount rate. The results are presented both in table form and in easy to understand graphs. The following graphs are presented:

- Cumulative 'Cash' Expenditure vs. Time
- 'Cash' Expenditure vs. Time
- Cumulative Present Value of Expenditure vs. Time
- Present Value of Expenditure vs. Time
- Cash Flow diagram
- Pie Chart (break down between Capital, Establishment, Routine Maintenance, and Corrective maintenance) for both 'cash and Present Value
- Cumulative Net Present Value vs. Time

For the SuDS system a set of 'Cost Treatment Trains' are presented which indicate the costs at each point in the treatment train. For the comparison of the two systems, results are presented for only the selected maintenance scenario, at the selected discount rate. The same results as presented above are supplied.

4.7 Damage Avoidance Cost tool

4.7.1 Background

The valuation of EGS is the most significant feature of the SEM. It allows for a fair comparison of SuDS and conventional stormwater management systems. While many tools are available for completing Stage 1, few are available for completing Stage 2. The DAC tool provides a quick, conceptual estimate of the EGS on a regional basis. This tool applies the 'Substitute Cost Principle' in valuing the EGS in the form of the quantity management and quality treatment supplied by SuDS. The assumption is then made that conventional systems externalize the equivalent value, in the form of EGS, onto the environment at large. The value of the goods and services supplied by SuDS is calculated by considering the cost of acquiring and managing a virtual treatment facility that would produce equivalent water quality treatment and quantity management. Typical treatment objectives considered achievable by the City of Cape Town (2009) for SuDS are presented in Table 4-4.

Figure 4-9 presents a schematic treatment train for the virtual treatment works, assumed by the SEM to be the most cost-effective way of treating stormwater discharge from a conventional drainage system, in order to meet the objectives described in Table 4-4. The water released to the receiving waters from such a facility is of a similar quality to that expected from SuDS designed to meet the same objectives. The hypothetical cost of treating conventionally managed stormwater in this way, may be termed the 'Damage Avoidance

Cost (DAC)'. Note that the virtual facility also allows for groundwater recharge, an important additional service offered by SuDS.

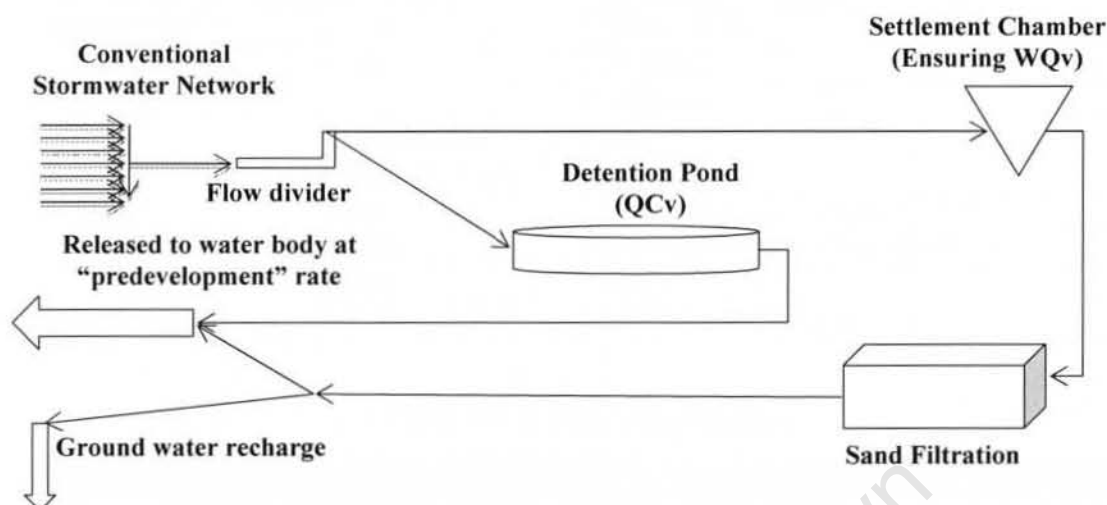


Figure 4-9: Schematic treatment train for virtual treatment works used to estimate the DAC

The DAC needs to account for both water quality and quantity (total volume and flow rate). In South Africa, the climatic conditions vary greatly from region to region. The model accounts for this by allowing the user to choose between one of five standard 24-hour design storms as appropriate for the sizing of the virtual treatment works. These include the four South African SCS storms (Southern African adaptations of the United States Soil Conservation Service design storms as described in Schmidt & Schulze (1987), and a 24-hour constant precipitation storm. For the same storm volume, higher intensity storms require larger and more costly treatment facilities than lower intensity storms therefore the constant precipitation design storm is the least costly and the SA SCS Type 4 the most costly. Other parameters that may be varied include the depth of runoff; the lag time and the discount rate.

In the computation of the DAC, care was taken at all times to ensure that the 'least cost principle' was adhered to. Over-estimation of the value of EGS, as discussed in Section 4.4.5, is a criticism frequently levelled at the Substitute Cost Method. Optimal performance of each unit process was thus assumed. For simplicity sake, the model assumes a number of parameters that influence the valuation of EGS. This is done to ensure the least cost alternative and is presented in Table 4-11. The three criteria that should be met to ensure the appropriate use of the Substitute Cost Method (Pagiola *et al.*, 2004) is listed in Table 4-12. The second column summarizes how the approach adopted in the DAC meets each criterion.

Table 4-11: Fixed input parameters in the DAC

Component	Parameter	Value
Flow Diversion	Capacity	Equals peak WQv Runoff
Sedimentation Chamber	Area	20% of WQv
	Depth	2m (max)
Filtration Chamber	K (m/s)	0.6m/day
	Depth of Filter	0.5m
	Head over Filter	2m
Detention Basin	Area	Sufficient to ensure detention of QCv
	Depth	Max depth = 2m; Average Depth = 1m
	Outlet	Orifice
Effective Impervious Area	15 ha	Sets optimum size of sand filter

Table 4-12: DAC Justification

Criteria	Justification
Equivalent Service:	The facility ensures equal treatment to a SUDS system as per Table 4-4.
Least Cost:	The DAC attempts to calculate the least cost of treating runoff from conventional systems using the most appropriate treatment works – in this case an online sand filter connected to an off line detention pond.
Willingness to Pay:	The “polluter pays” principle is widely accepted in law and it is therefore appropriate that the cost of treatment is accounted for. In conventional systems, these costs are externalised onto the environment resulting in the potential loss of natural capital. It is likely that there will be resistance to service charges being levied for stormwater treatment measures but this is not an excuse for not doing so.

4.7.2 Design of unit processes

4.7.2.1 Flow Diverter/ Outlet

The cost of the flow diverter (structure designed to divert excessive flow to an offline facility) and the pond outlet (structure designed to release stored water at a specific rate) are assumed to be the same allowing for minor modifications. The cost estimate is based on a design developed by Graeme McGill Consulting (2010) for offline detention pond inlet/outlets. Essentially the inlet/outlet allows a design flow. Any flow over this design flow is diverted to an offline detention pond. The design is shown in Figure 4-10: Inlet/Outlet Design. The following modifications were assumed for the DAC tool to function:

- For the low diverter the outlet was closed (red cross in Figure 4-10) i.e. only acting as an inlet to the pond once the treatment facility is full or the peak flow has been exceeded.
- For the pond outlet the outlet orifice size was set by the model dependent on the required flow i.e. only acting as the outlet.

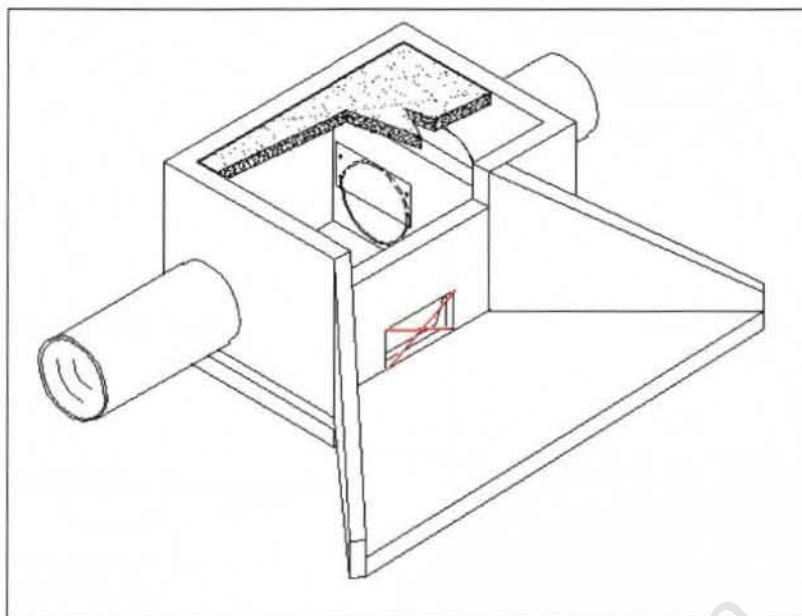


Figure 4-10: Inlet/Outlet Design

It was necessary to have an inlet and an outlet in order to avoid all the runoff being treated by the quality treatment facility. The cost of the diverter would not vary significantly with design flow and was not modelled to do so.

4.7.2.2 Sedimentation chamber & Sand Filter

The costing of the sedimentation chamber and sand filter is based on a conceptual design by Jeffares & Green (2008) to estimate the cost of managing polluted stormwater at specific sites in Cape Town. However in order to ensure a 'least cost alternative' the design was altered. Most notably the need to consider floatation due to groundwater was ignored, as were ground water a design issue the design for infiltration would need to be reconsidered. Other adjustments were made to the depth of the sand filter and the dimensions of the facility (head of water). These were all adjusted in line with the limits suggested in Debo & Reese (2003) for an Austin Partial Sedimentation Sand Filter (APSSF) thereby ensuring the minimum cost per unit stormwater treated.

The design of the Sedimentation and the Sand Filter chambers are shown in Figure 4-11. It is worth noting that the water level is balanced between the two chambers.

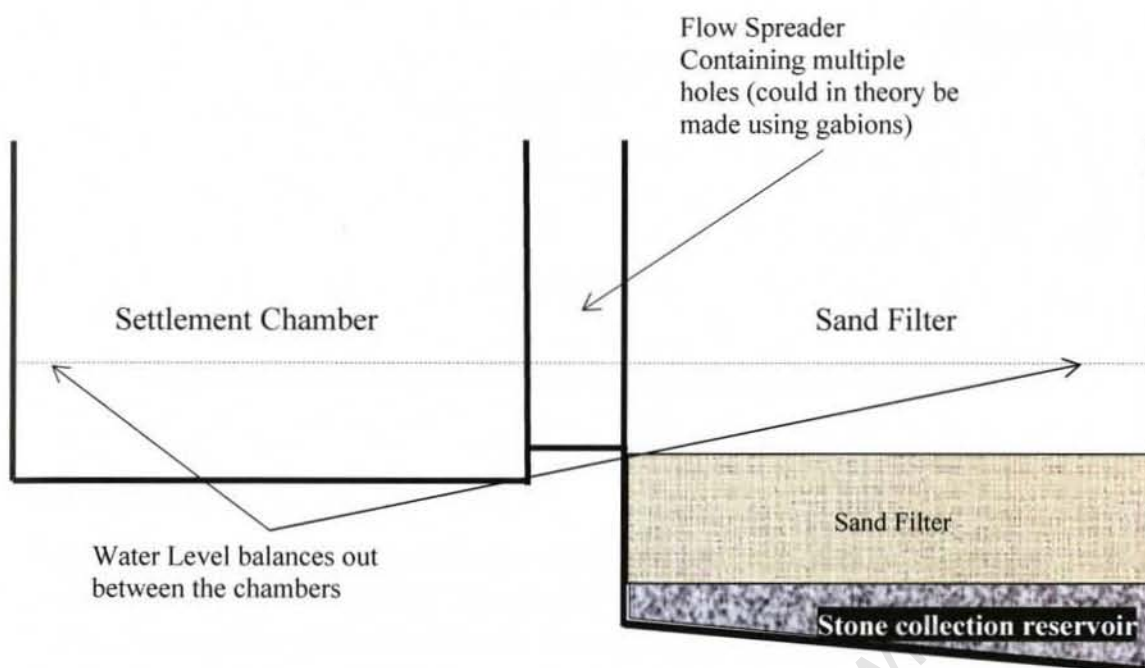


Figure 4-11: Sedimentation and filter design

4.7.2.3 Infiltration chambers

A number of infiltration techniques were considered including boreholes, infiltration basins and infiltration trenches. The lifecycle costing, especially maintenance, of a recharge borehole is difficult to estimate. This system would require the detention of treated stormwater which would require additional land take and in many cases where SuDS would infiltrate this would not be necessary i.e. where the soil is sandy. The use of infiltration basins requires extensive land areas. Stone fill soakaway's were selected due to the minimum land-take and the need to only infiltrate without treatment as the water would already have been treated, thereby minimizing maintenance.

4.7.2.4 Quantity control pond

The cost of the quantity control pond was estimated per cubic meter. It was assumed that a maximum depth of 2 m would be used for health and safety reasons; hence the average depth of the pond would be 1 m. The design is shown in Figure 4-12.

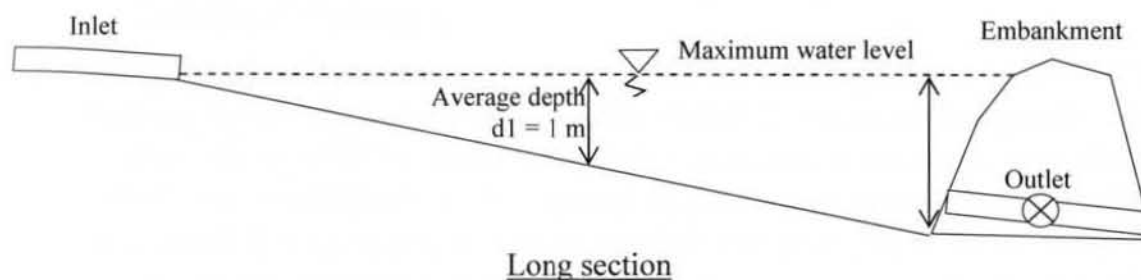


Figure 4-12: Conceptual design of quantity control detention pond

4.7.2.5 Land Take

Land take is estimated by calculating the total land take required for the quality treatment facility and quantity control pond. The facility is then assumed to be square, with 5 m, to allow for access to the whole site for maintenance, between any parts of the facility and the fence, as indicated in Figure 4-13.

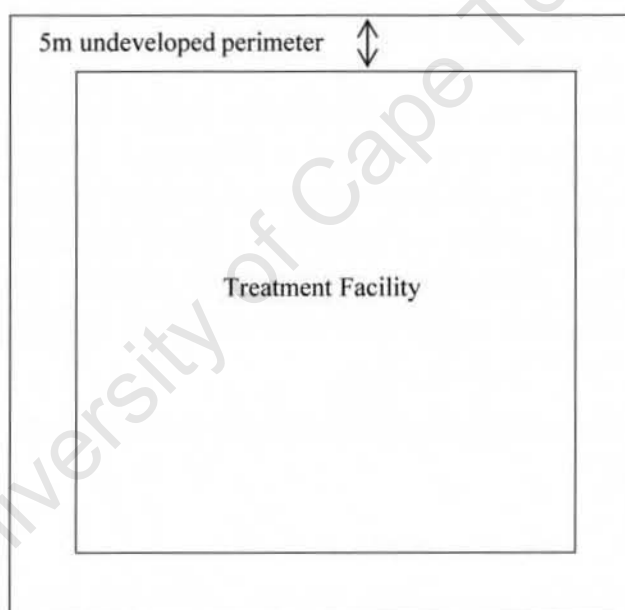


Figure 4-13: Calculation of Land Take

4.7.3 Sizing the unit processes

An important function of the DAC tool is to size a virtual treatment facility. The following section details how the virtual facility is sized, and why the order is important.

4.7.3.1 Calculation Procedure

The calculation procedure for the DAC follows the process outlined in Figure 4-14. The initial parameters for the analysis are entered in Step 1. The model automatically completes Steps 2 to 6. The order of the model's calculation procedure is significant as it ensures that the facility's use is optimized i.e. the treatment facility is fully utilized before the detention facility is required, ensuring a 'least cost alternative'. The hydrographs for the Water Quality volume (WQv) and Quantity Control volume (QCv) storms are modelled. The treatment facility is sized to ensure that it has sufficient capacity based on the WQv Storm. The QCv Storm is routed through the facility and excess runoff that the quality treatment facility cannot manage is routed through a quantity control pond that releases runoff at a reduced rate (30% of post development).

Step 7 involves the separate calculation of the costs for treatment and the 'land-take'. The land-take accounts for the fact that real treatment facilities would have to be located somewhere in the city and that land will have to be acquired at some cost. The SEM allows this cost to be included, if so desired.

The user calculates the final DAC in Step 8. The final DAC includes an amount for treatment and an amount for land-take (if desired). The virtual facility initially assumes a catchment with an effective impervious area (EIA) equal to 15ha – an estimate of the area that will require a sand filter of roughly optimal size based on guidelines for sand filters in Debo & Reese (2003). Debo & Reese (2003) recommend up to 20.2 ha (50 acres) may be treated with a similar facility. Assuming an average runoff factor for developed areas of 0.75 (a generally conservative estimate likely) would result in a EIA of 15ha. This is to ensure that the cost of developing and operating the facility is based on the 'least cost principle'. The costs (treatment and land-take) associated with EIAs larger or smaller than 15ha are then determined pro-rata.

The final DAC is then exported to the main SEM spreadsheet in Step 9.

4.7.3.2 Design storms

Hydrographs are calculated depending on the parameters entered by the user. Two hydrographs are generated, one for the WQv storm and one for the QCv storm. The WQv hydrograph is used to size the facility for water quality treatment and the QCv hydrograph is used to size the facility for water quantity management. The hydrographs are calculated using the approach taken in Schmidt & Schulze (1987). The calculations do however assume a 100% runoff from the catchment. Therefore, the catchment area is the Effective Impervious Area, as defined in Section 4.7.3

The flow is calculated for every minute, based on the parameters set by the user. The result is shown in Figure 4-15.

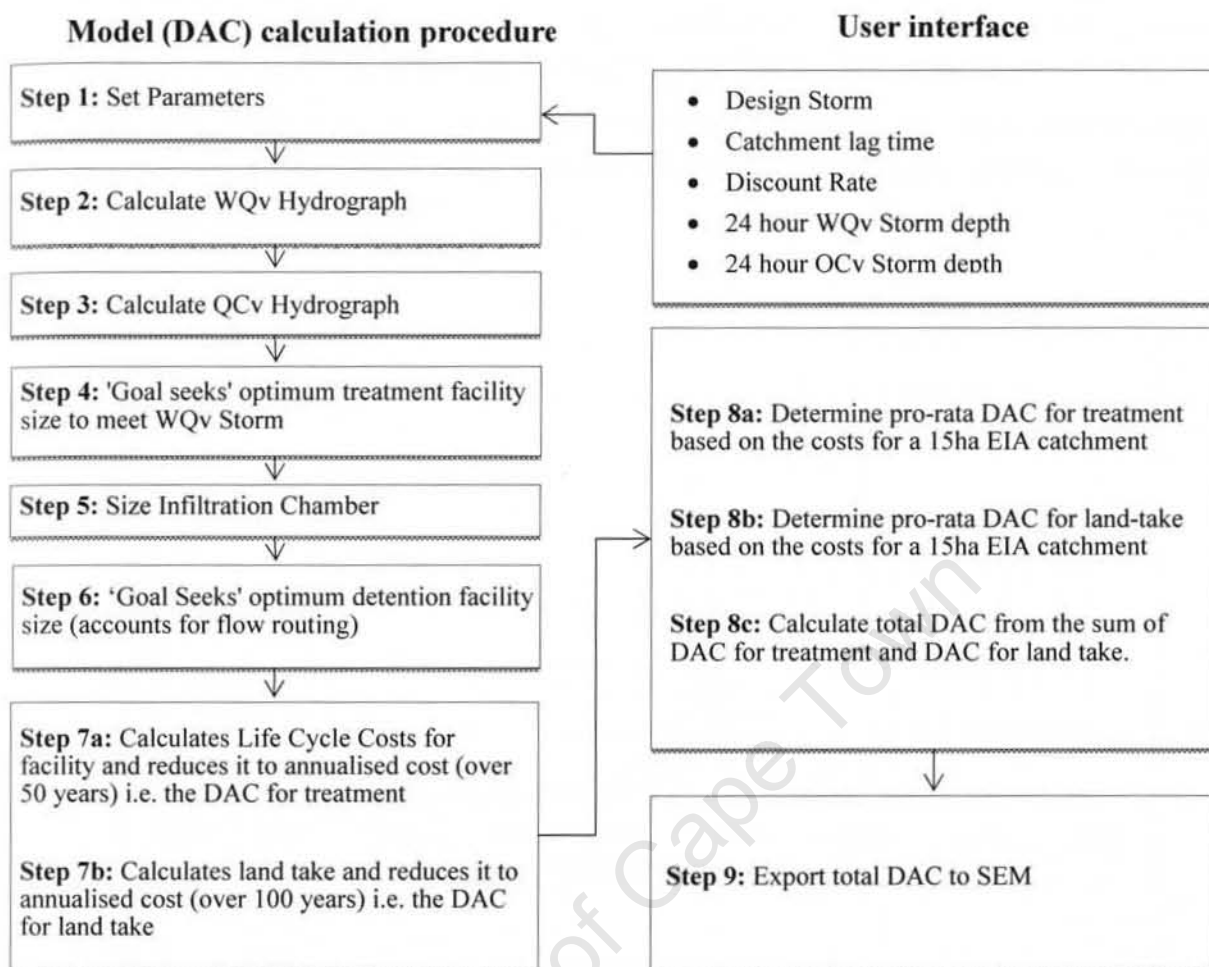


Figure 4-14: DAC tool calculation procedure

4.7.3.3 Routing through the facility

Essentially the facility acts as a storage facility or 'reservoir' while it treats the runoff. The size of the facility is set, and the storm routed through the facility using the reservoir routing formulae, as shown in Equation 4.

$$I-O = \frac{dS_t}{dt} \quad (4)$$

Where: I = Inflow (from storm hydrograph); O = Outflow (through sand filter, detention pond); S_t = Storage (within settlement chamber, sand filter, detention pond, infiltration chamber); and t = time.

The assumption is made that the virtual treatment facility is fully utilized before any runoff is diverted into the quantity control pond. A very simplified overview of the logic and formulae behind the modelling of the virtual facility is given in Table 4-13.

The 'goal seek' macro, resizes the components until the WQv Storm can be fully routed through the virtual treatment facility, and the QCv storm can be fully detained within the quantity control detention pond.

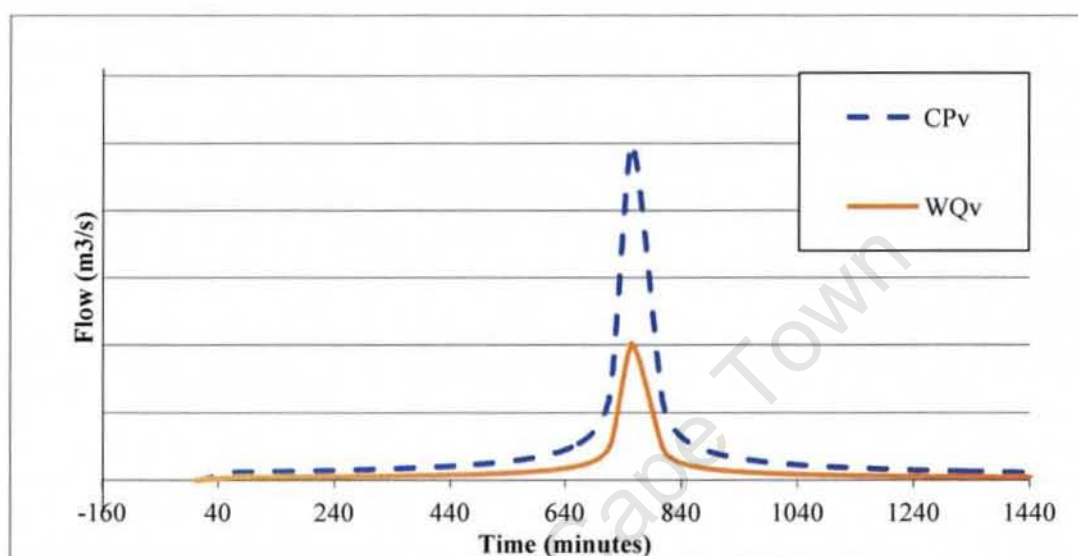


Figure 4-15: Storm Hydrograph

4.7.3.4 Effective impervious area/ directly connected impervious area

The term effective impervious area (EIA) recognizes that not all impervious areas are connected to the stormwater system. In some cases impervious areas could be surrounded by gardens or solid walls which result in runoff being detained or managed on site. EIA is basically the impervious cover that provides stormwater directly into the stormwater system. For these purposes, it is further defined as the equivalent area of impervious surfaces that results in 100% runoff for the design storm depth.

This can be calculated by multiplying the sum of all connected impervious areas by a runoff factor in the range of 0.9-1 based on the sites characteristics, which adjusts impervious area to EIA. Alternatively, where the system is modelled it is possible to divide the total runoff by the WQv storm depth.

Table 4-13: Summary of how inflows/outflows are calculated for different unit processes in the treatment trains

Stage	Explanation		
	In	Out	formulae
Diverter	Accepts peak flow of WQv storm, until treatment facility is full, additional runoff is stored in the detention pond		N/A
Sedimentation	From flow diverter	Same depth as in sand filter chamber	N/A
Sand filter	Same depth as in sedimentation chamber	Through sand layer	Outflow through sand filter = kiA A = Area k = coefficient of permeability i = hydraulic gradient
Infiltration	Flow from sand filter	Into soil until soakaways is full, overflow to "water course"	Outflow through soakaways = kiA A = Area k = coefficient of permeability i = hydraulic gradient
Quantity control pond	Overflow from Treatment facility	Through orifice	Outflow from quantity control detention pond = $CdA\sqrt{2gh}$ Cd = Coefficient of discharge A = Area of orifice g = gravity (9.81m/s^2) h = Head (m)

4.7.4 Operations and Maintenance

Operations and maintenance costs and frequencies were estimated using the 'Fact Sheets' considering a low maintenance level (ensuring quantity and quality performance with little or no regard for amenity). The costs were reduced to present values using the same economic module used for calculating the costs related to the system.

4.7.5 Valuation of EGS

The valuation of the cost of treatment within the virtual treatment facility and detention pond, and for land take is presented separately as well as cumulatively. The cost, 'the DAC', is annualized over the life cycle of the virtual facility. The cost is reduced to a unit rate per EIA (Section 4.7.3). This has been done for two reasons:

- In order to ensure the least cost alternative it is necessary to make use of the 'economies of scale' as the stormwater will be treated on a regional basis. It is assumed the facility can treat up to 15ha, therefore if a facility were to be only 5ha it may not be the least cost solution.
- It may be useful to assign the externalised costs to individual properties. This would most easily be done based on EIA.

4.8 Rainwater and Harvesting Tool (RWHR Tool)

4.8.1 Background

The Damage Avoidance Cost tool accounts for the regulating value of a SuDS system. However, the provision of goods is not considered. While it is relatively simple to calculate the value of flowers harvested or the fish caught, it is not as simple to determine the value of rainwater collected and reused. In order to assist users in South Africa the Rainwater and Harvesting Tool (RWHR) was put together.

4.8.2 Importance of proper calculation

It is evident that the calculation of Annual Collectable Runoff (ACR) is not a good estimate of the volume of water collected and reused. For example a 5000l tank with a catchment of 50m² will collect a higher percentage of the runoff when compared to a 5000l tank with a catchment of 500m² as the 5000l tank will become full and not be able to accept more runoff which will then not be collected and available for reuse. To simply use an estimate of the ACR, which is what could possibly be collected would be misleading.

4.8.3 Calculation procedure

The tool essentially uses reservoir routing, Equation 3, and the Rational Method, Equation 5, to model the system on a daily basis. Inflows are determined using the rational method and actual rainfall data. The tool allows for up to 10 years' worth of daily rainfall data to be entered. Out flows are entered on a monthly basis as the outflow may vary with the season. The logic of the calculation procedure is outlined in Figure 4-16.

For the purposes of comparison the model also calculates the ACR. This may be used to inform the designer on optimizing the design.

$$Q=CiA \quad (5)$$

Where: Q = Flow; C = Runoff coefficient; i = Intensity; and A = Area.

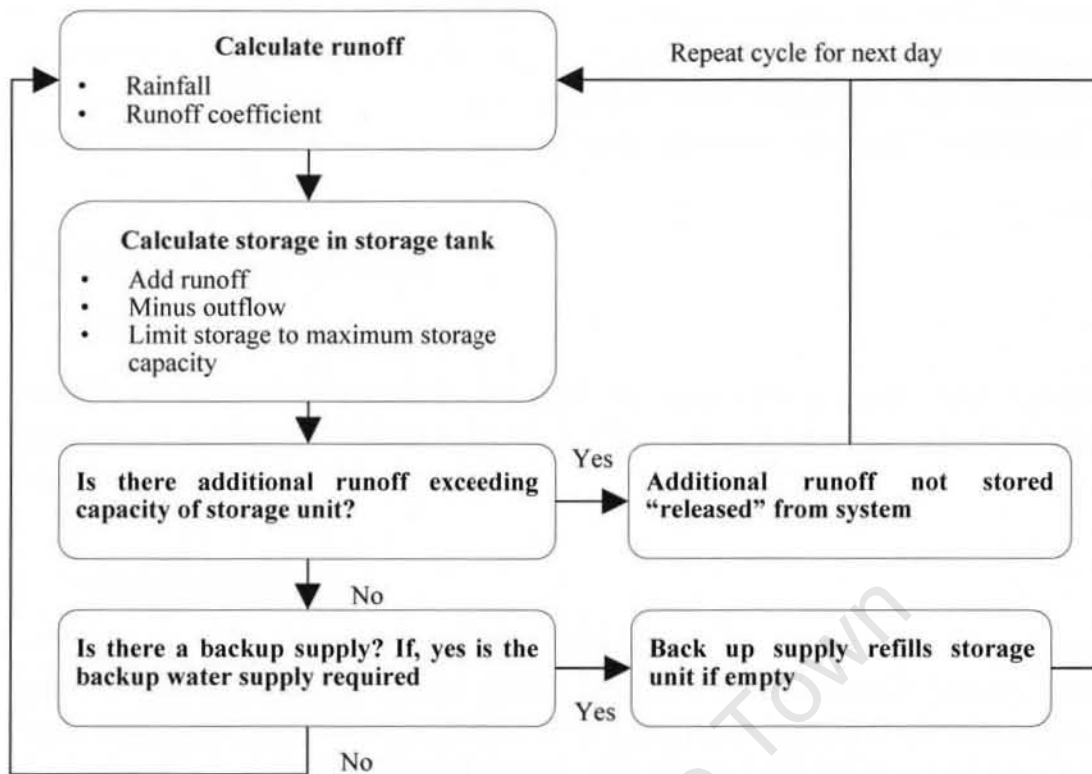


Figure 4-16: Rainwater harvesting and reuse tool calculation logic

4.8.4 Results

The tool calculates the following results for the design:

- Total runoff (for entire analysis)
- Annual average runoff (based on daily rainfall data)
- Total water captured (for entire analysis period)
- Annual average water captured
- Total water **NOT** captured (for entire analysis period)
- Annual average water **NOT** captured
- Total water consumed (for entire analysis period)
- Annual average water consumed
- Total water required from back up and days requiring back up supply (for entire analysis period)
- Annual average water required from back up & days requiring back up supply
- Percentage of storms contained
- Annual collectable runoff

The number of results allows a user to optimize a design ensuring that 90% of storms are managed by the storage unit (90% is the commonly used storm for water quality management for example: Debo & Reese (2003) and Maryland (2000)). Based on these results and by entering an appropriate value for water, the total value of water consumed is calculated.

4.9 Critique of the Model

4.9.1 The Model's Computation

The model's life cycle costing analysis computations are relatively simple. Due to a lack of local data the model itself undertakes repetitive calculations for the user and then produces the results in a set of simple charts/graphs.

4.9.2 Valuation of EGS

Undoubtedly, the biggest criticism of this model will be directed at the approach to accounting for the lack of quantity and quality treatment in conventional systems. However this model should be applied more generally. If in a specific location a lower cost approach is found, this local approach could be substituted. This lower cost option would have to meet the same quality and quantity output criteria. Specific critiques of each aspect of the model are discussed below:

- i) Attenuating peak flows in a conventional design will require detention, decreasing the cost for attenuating peak flows is unlikely.
- ii) Sand filtration is one of the cheapest options available, in that it both treats, but also detains the same runoff, reducing the need to have a second facility to attenuate flow. It is also a gravity fed solution that functions when there is runoff, and does not require a fulltime staff presence, providing maintenance procedures are adequate.
- iii) Urban development has limited the natural recharge process and the impacts of the reduced infiltration have to be recognized.
- iv) The model allows for the entry of data relating to additional amenity and biodiversity impacts. It does not however offer a means of estimating these for a number of reasons that include:
 - a) Variability in estimated values, needs to be assess on a site-by-site basis;
 - b) The relation between level of maintenance and value of amenity and biodiversity;
 - c) The variability in social values within South Africa; and
 - d) Problems with estimating the differences between conventional and SuDS systems in a fair manner, especially social values.

While the model allows data to be entered, extensive research is required on a site-by-site basis to allow a realistic consideration of the value of amenity and biodiversity. The approach

presented alongside the SEM only requires quantity and quality aspects to be considered. By designing systems to handle the same design storms risk is managed equally by both systems. Should a deeper analysis be needed which considered EGS this would need to be done in a fair and equivalent manner.

4.9.3 Conclusion of critique

Care has been taken to ensure that all the requirements set out in Table 4-1, and therefore the aims of the SEM have been met. The SEM provides a fair basis for evaluating two or more alternative urban stormwater designs. The model's DAC tool underestimates the cost of the treatment works, and hence is a 'least cost option'.

University of Cape Town

5. Application of the SEM

The three examples that follow have been selected to demonstrate the application of the Simple Economic Model, its components, and the proposed procedure for undertaking such studies. Detailed instructions are included in Appendix C. They cover a range of situations (different scales) and motivate how the ecosystem goods and services were modelled

- i) Residential House: Rainwater Harvesting & Reuse
 - a) Single SuDS option
 - b) Rainwater Harvesting & Reuse tool, DAC tool – only considering WQv storm, excluding land value
- ii) Large paved public open space – Grand Parade
 - a) Design Comparison, DAC tool – considering WQv storm, including land value
- iii) Commercial development – Mitchell’s Plain District Hospital
 - a) Multiple technologies/SuDS options, design comparison
 - b) ‘Cost’ Treatment Train

5.1 Example 1: Rainwater Harvesting

The purpose of this example is to consider the costs and benefits of retrofitting a residential house with rainwater harvesting tanks, in order to better manage stormwater.

5.1.1 Site overview

The site is a fully developed residential property. Approximately 65% of the plot has been covered with impermeable surfaces directly connected to the municipal infrastructure. The owners wish to reduce their water rates account and more sustainably manage their stormwater. While it will be costly to retrofit the whole property to meet the quantity and quality performance requirements set by the City of Cape Town’s “Management of Urban Stormwater Impact Policy”, the owners are interested in whether rainwater harvesting could be economically beneficial.

The garden, especially surrounding the pool needs to be watered (non-indigenous) throughout the year.

5.1.2 Rain Water Harvesting

Rainwater harvesting and reuse is proposed to manage runoff from the roof (sub catchments S1, S3, S6 in Figure 5-1), the two tanks are designed to have a minimum of 1 m³ of storage available which acts as a water butt. Essentially this would be temporarily detained and

release over an extended period e.g. 24 hours). This is the equivalent of 20mm over a roof of 100m².

- Tank 1 will manage in excess of the first 10mm on catchments S3,S6. The stored water will be used for flushing toilets (2 toilets) estimated to use approximately 60 ℓ/day throughout the year
- Tank 2 will manage runoff in excess of 20mm on catchment S1. The stored water will be used to supplement pool water, and for garden irrigation. Consumption is estimated to vary between 0 ℓ/day during June/July up to 250 ℓ/day during January/December

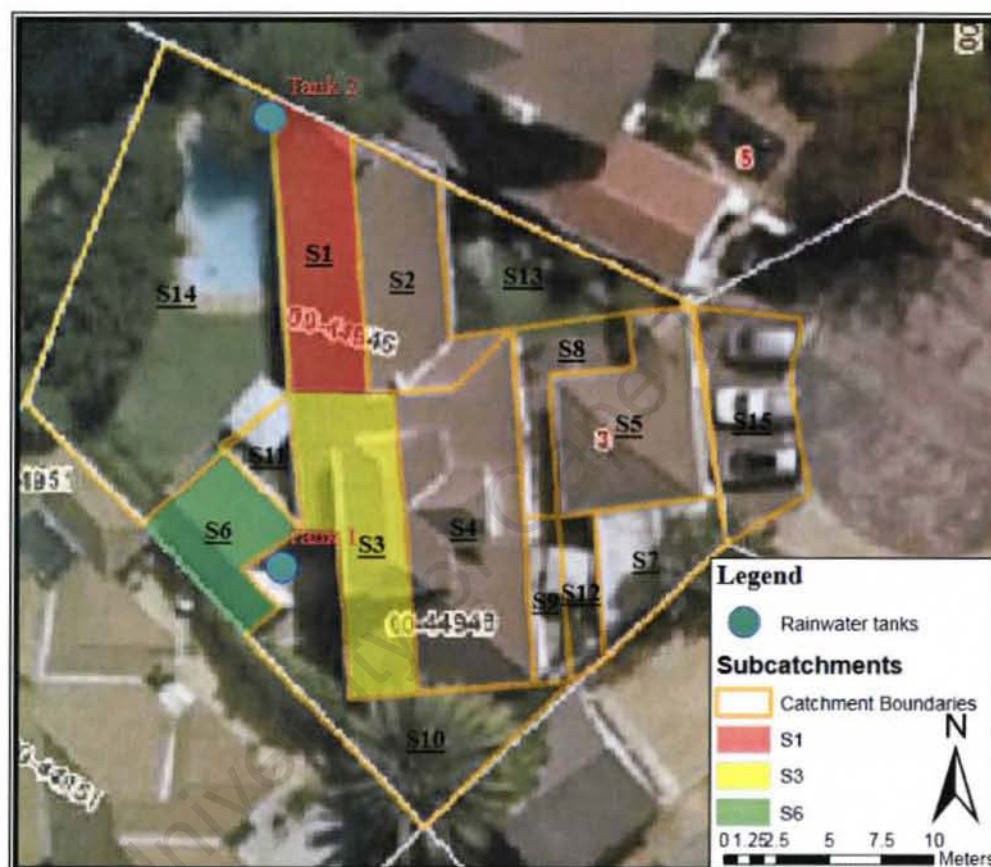


Figure 5-1: Residential house to be fitted with rainwater harvesting tanks

5.1.3 Life Cycle Costing

The following costs, shown in Table 5-1, derived from the 'Fact Sheets' are considered reasonable for the purposes of this example and have been entered into the Individual Component Design spreadsheet. The High Maintenance scenario assumes a medium level of maintenance with maintenance sub-contracted. The Low Maintenance scenario assumes the home owner undertakes the regular maintenance.

Tank 1 will be significantly more expensive as it will need to be built on a stand to elevate it, thereby allowing gravity flow from the tank to the point of use.

Table 5-1: Rainwater Harvesting Life Cycle Costs

Task		Typical rates, if tasks not performed by home owner.		Scenario (total costs)	
		Tank 1 (R)	Tank 2 (R)	High Scenario (R)	Low Scenario (R)
Capital		16000	8000	24000	24000
Establishment		0	0	0	0
Inspections		160	160	160	0
Routine Maintenance	First Flush Cleaning	150	150	150	0
	Roof Cleaning	200	100	300	300
	Roof Cleaning Setup	300		300	300
Irregular Maintenance	Sediment Removal	200	200	400	400

5.1.4 Benefits

As indicated in the analysis the rainwater harvesting system will remove a minimum of 2 m³ (1 m³ for each rainwater tank) from the storm volume. The DAC tool has been used to estimate the value of quantity and quality management. Additionally there are further benefits in the form of reduced water usage; these have been evaluated using the City of Cape Towns proposed tariffs for sanitation and water. It is worth noting that sanitation is linked to the volume of water consumed thus the total benefit from reduced water consumption is the sum of the reduction in water and sanitation fees.

Table 5-2: Water reuse benefits

	Water (per kl)	Sanitation (per kl water)	Total (9.12+9.12×0.7)
Cost (R's)	9.12	3.27	12.39

In order to assess the benefits of the system it is necessary to estimate the volume of water that is available for reuse. This was accomplished in two ways. Firstly, by calculating the Annual Collectable Runoff, as shown in Table 5-3. Secondly, by modelling the system and determining the Modelled Collectable Runoff (MCR) inflows and outflows - over a year/s, as shown in Figure 5-2 and Table 5-3.

Figure 5-2 is an output from the RWHR Tool discussed in Section 4.8. Figure 5-2 shows the volume of storage in Tank 1 as well as the volume not collected when runoff volume exceeds available storage capacity. It highlights that during November to April the Tank 1 is generally empty (except immediately after a storm event). On the other hand during winter (May to October) Tank 1 is generally full and cannot contain all the runoff.

Table 5-3 it is clear that there is a significant difference between the ACR and MCR, The main reason being that the storm events where runoff exceeds available storage volume

within the system is not accounted for in the ACR calculation which ignores storm event size and available storage capacity. This highlights why undertaking a MCR modelling is vital. It is also worth noting that in the modelling, the system assumptions need to be made about water consumption. These will be based on what the water is used for, be it the flushing of toilets which is simple to estimate or the watering of gardens which may be more difficult.

Table 5-3: ACR vs. MCR

	ACR (kl)	MCR (kl)	Consumed (kl)
Tank 1	33	18.6	16.4
Tank 2	18.2	18.5	13.6

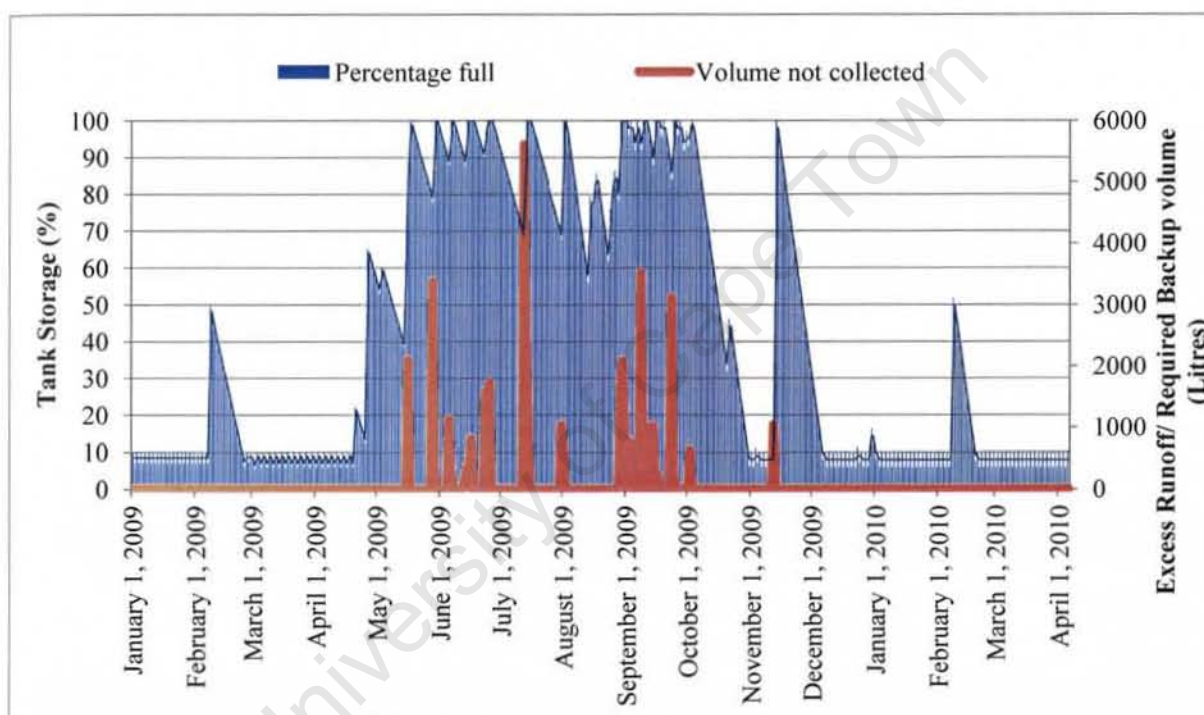


Figure 5-2: Rainwater harvesting modelled using precipitation records for 2008/2009 (Tank 1)

The lower (more conservative) estimate of storage/consumption was used to estimate the value of the water consumed. Clearly to be more accurate it would be necessary to model multiple years, varying the consumption scenarios, and then use an average. However the purpose is it to demonstrate the model, not detail the design of SuDS systems.

Based on the results in Table 5-2 and Table 5-3 the annual benefits shown in Table 5-4 are estimated due to water that is reused. These benefits are solely for the provision of goods i.e. the water. It does not consider the regulating services provided by removing and treating the runoff.

Table 5-4: Water consumption benefits

	Estimated water savings (kl)	Value of water (R/kl)	Benefit (R)
Tank 1	16.4	12.39	200
Tank 2	13.6	12.39	170
Total	30	12.39	370

The other benefit that needs to be assessed is the two tanks stormwater management capability. An analysis of the DAC (water quality and quantity management) was conducted to determine the value of the regulating services provided through the rainwater harvesting system. The input parameters for the analysis are shown in Table 5-5. The Results are shown in Table 5-6.

Table 5-5: DAC Parameters

DAC Parameter	Tank 1	Tank 2	Reason
Water Quality Storm Depth (mm/24hrs)	10	20	Storm depth each tank manages
Quantity Control Storm Depth (mm/24hrs)	10	20	Entire volume treated for Water quality. Therefore no QC storm
Lag Time DAC (default 6 minutes)	30	30	30
Discount Rate (%)	4	4	Used for analysis results
Reduction in predevelopment flow for QCv (%)	0	0	No management of QCv Storm
Recharge (as% of WQv)	0	0	No infiltration
SCS SA Storm Type	1	1	
Total Area (m ²)	100	50	Catchment for each tank

Table 5-6: Stormwater management benefits

	DAC (R per year)
Tank 1	90
Tank 2	74
Total	164

It is now possible to undertake a 'fair and equivalent' economic analysis of the implementation of rainwater harvesting tanks, as both systems are being compared on an equal basis.

5.1.5 Economic analysis

Based on the criteria and the above-mentioned results an analysis of the two rainwater tanks was conducted making use of the Single Component Analysis module. The application is

shown in the Figures 5-3 to 5-6. Figure 5-3 and Figure 5-4 clearly indicate that the maintenance of the system by a contractor will result in a significantly higher maintenance burden.

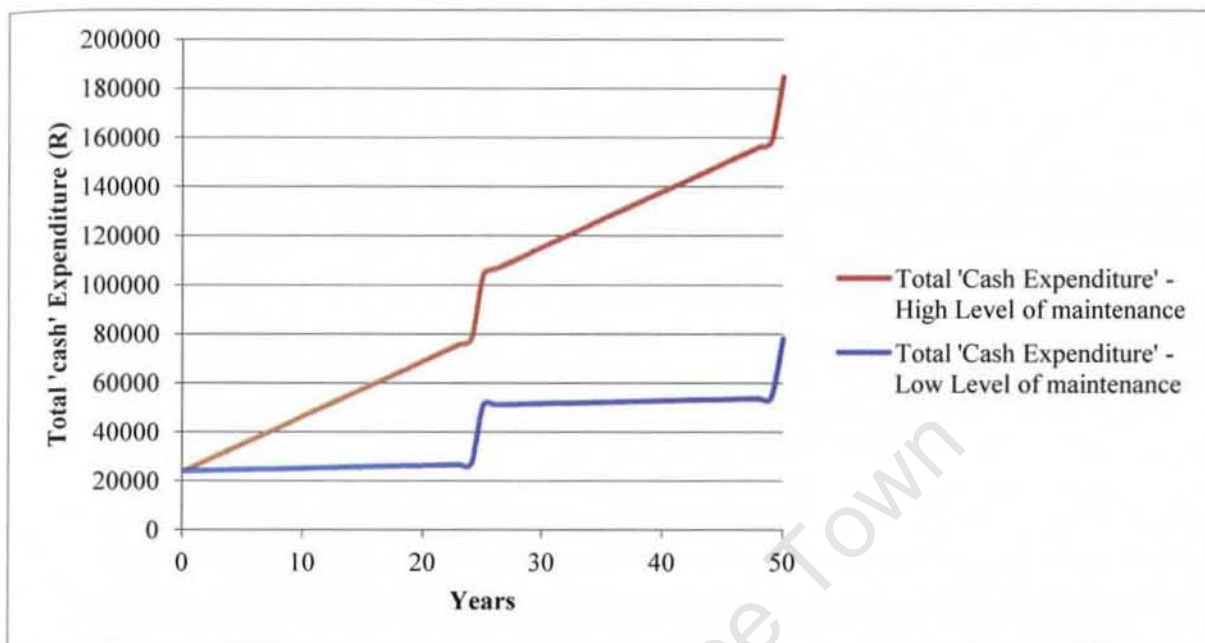


Figure 5-3: Rainwater harvesting system cash expenditure over 50 years

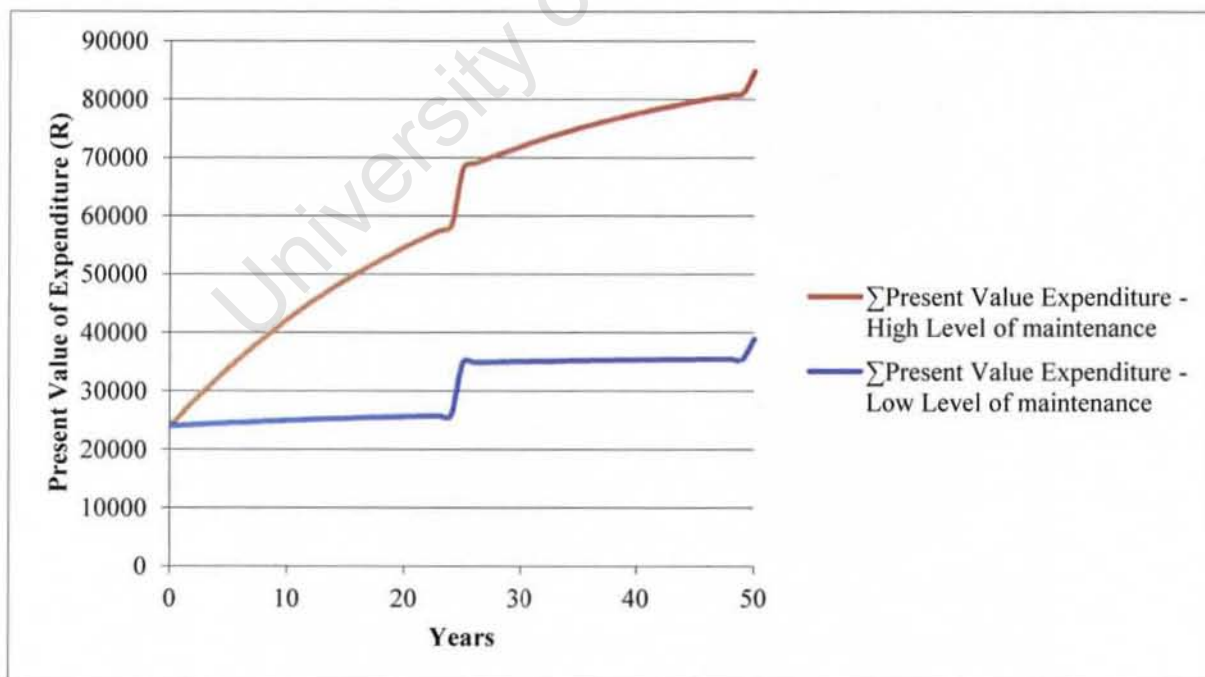


Figure 5-4: Rainwater harvesting system present value of expenditure over 50 years

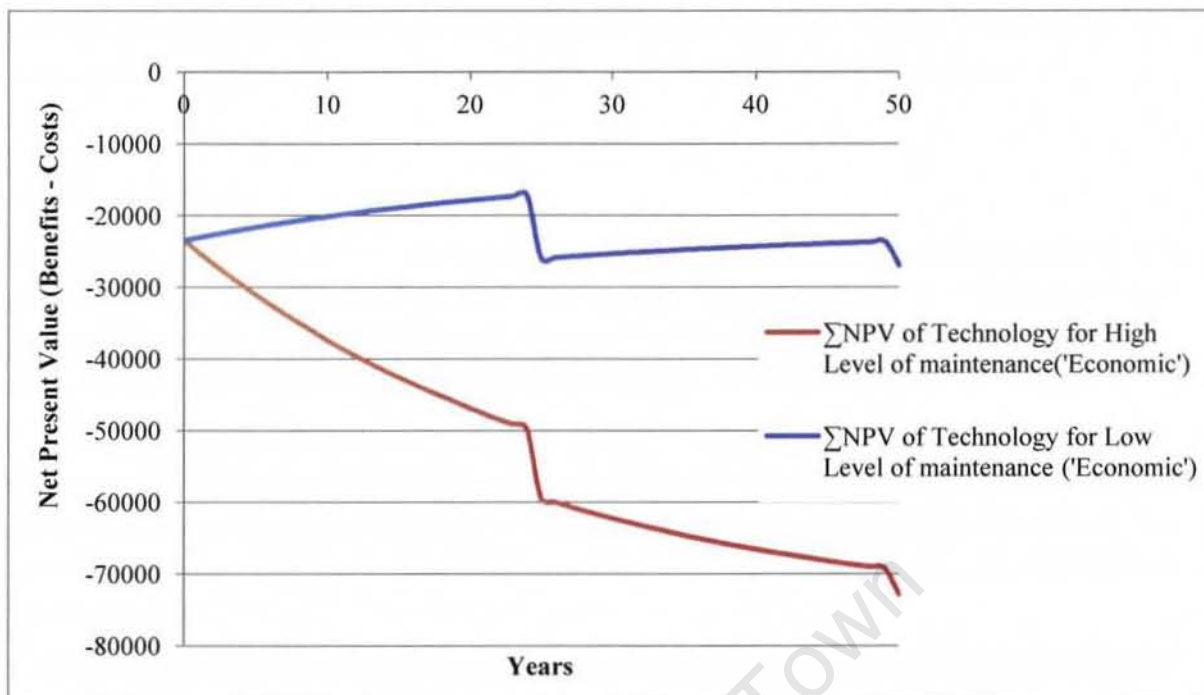


Figure 5-5: Net Present Value (Benefits – Costs) rainwater harvesting system over 50 years

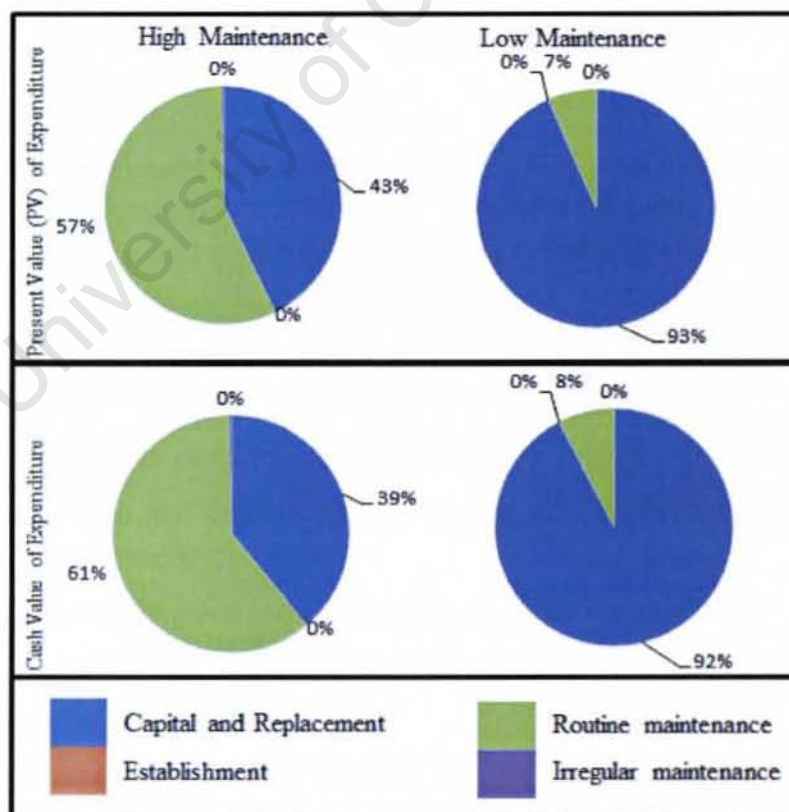


Figure 5-6: Rainwater harvesting system cash expenditure breakdown over 50 years

Figure 5-6, demonstrates that it is most economical if the tasks required for maintaining the system are undertaken by the home owner. The results in Figure 5-3, Figure 5-4 to Figure 5-6 are useful for explaining the need for maintenance and motivating the home owner.

5.1.6 Conclusions

The model has been applied to considering the economics of retrofitting rainwater tanks to a residential home to supply water for gardening and the flushing of toilets. The example has demonstrated the use of the RWHR tool, the DAC tool and the Single component analysis module. The SEM has been used to calculate the benefits of the system.

It is clear that should the home owner personally undertake the routine maintenance i.e. incur 'no cost', the costs of the system will essentially be the cost of the installation as the benefits equal the irregular maintenance costs. If however all maintenance is outsourced, the system will require on-going expenditure and the benefits will not cancel out the regular maintenance costs.

The results have been presented in a graphic, user-friendly manner that easily informs a designer or homeowner. The results also clarify that in order to reduce the costs or make the system cost neutral after installation, the homeowner would need to take on the responsibility for on-going maintenance.

5.2 Example 2: Grand Parade – Public open space

5.2.1 Context

The City of Cape Town invested in the first major permeable paving scheme in the Western Cape when it paved approximately 0.25ha of the 2.5ha Grand Parade site using permeable paving. The Grand Parade offers a useful case study on the economics of upgrading a site in order to manage stormwater impacts incorporating SuDS. This site was already serviced by conventional stormwater systems. According to UWM Group (2009) the design:

- i) "Minimizes stormwater management issues which simplifies planning;
- ii) No need to install costly stormwater, water collection or detention systems;
- iii) Eliminates collection and detention areas, increasing the effective developable area, saving the developer money;
- iv) Lessens the chance of erosion and water seeping into basements;
- v) Lowers maintenance costs because permeable paving surfaces require fewer repairs and need to be resurfaced less often;
- vi) Channels water to the root systems of plants and trees, resulting in healthier vegetation; and
- vii) Removes a significant percentage of pollutants at point."

- vi) Channels water to the root systems of plants and trees, resulting in healthier vegetation; and
- vii) Removes a significant percentage of pollutants at point.”

Figure 5-7 shows the site before and after upgrading. It is clearly aesthetically more pleasing (a consideration in any SuDS design), and although a number of trees were removed during construction, these have been replaced with indigenous trees which will improve the aesthetics and environmental aspects of the development.

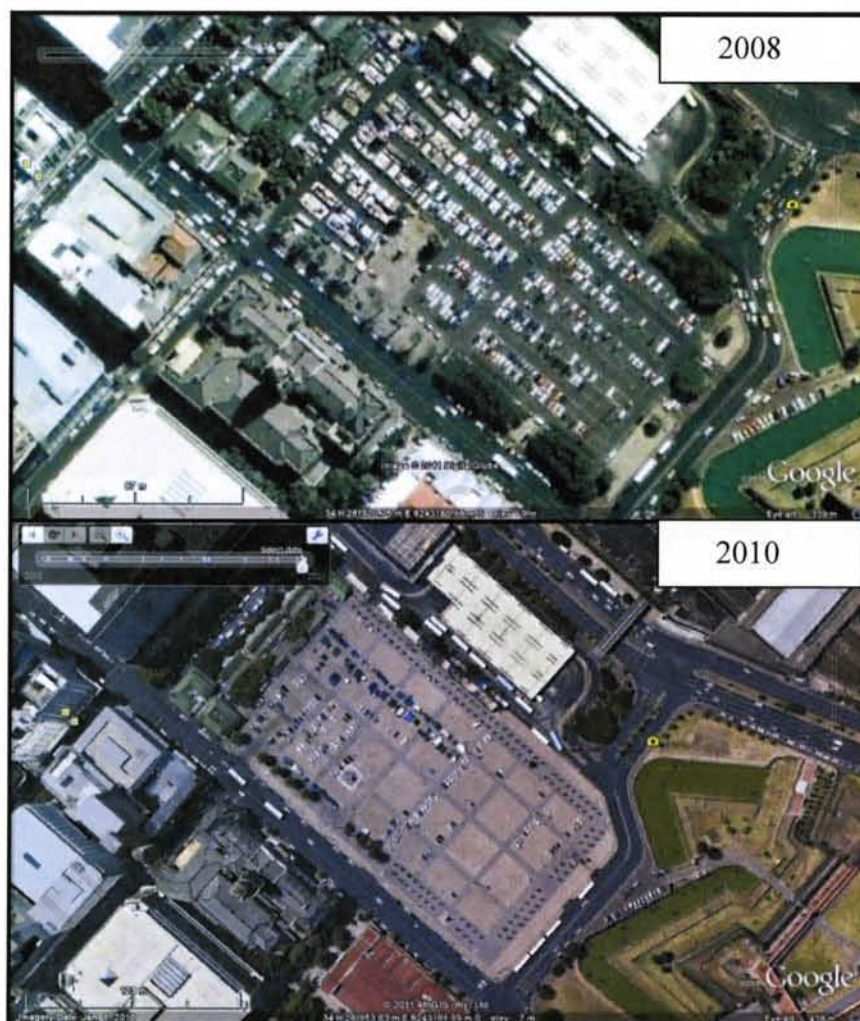


Figure 5-7: Site prior to (2008) and after development (2010) (Google Earth, 2011)

This case study is based on the Grand Parade site. In practise the Grand Parade has a daily maintenance schedule to manage litter (solid waste) resulting from the traders market. This case study considered only maintenance required for stormwater management. The original construction rates have been sourced and adjusted to October 2010 and fact sheets have been used to estimate the maintenance costs. All the estimates consider only stormwater aspects.

5.2.1.1 Site & Catchment characteristic

- i) The site falls within the City of Cape Town's Central Business District which may be considered a high pollution area
- ii) The conventional drainage system releases stormwater into the City's harbour as indicated in Figure 5-8, as a result quantity control is not a concern, quality management however remains vital.

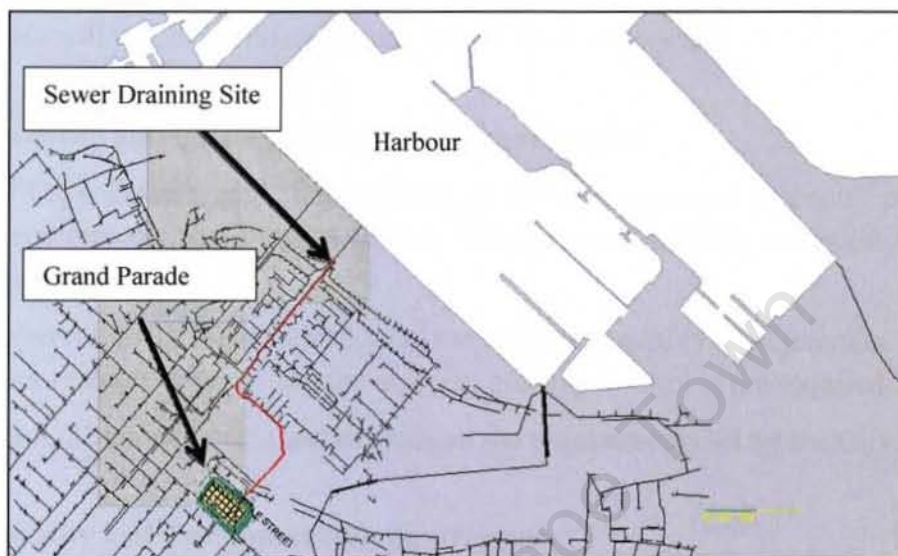


Figure 5-8: Conventional sewer discharging into the city's harbour (GIS data supplied by City of Cape Town)

This analysis will consider the whole Grand Parade, and what were originally sidewalks, as indicated in Figure 5-9. This requires approximately 25,000 m² of paving, of which approximately 2,500 m² was developed as permeable paving draining 20,000 m² following the recent upgrading.

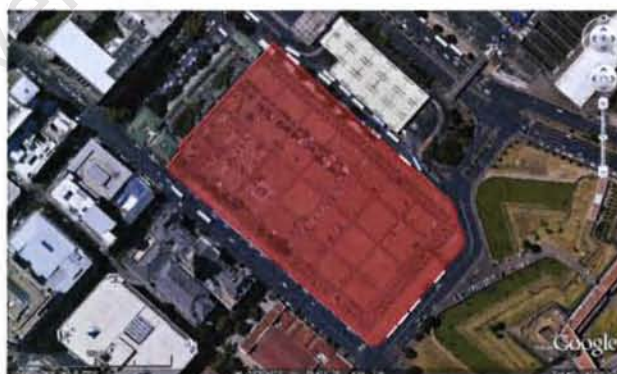


Figure 5-9: Site Overview (Google Earth, 2011)

5.2.1.2 Proposed land use characteristics

- i) Site is used for parking approximately 200 vehicles.
- ii) The remainder of the site is used for a trading market.

5.2.1.2 Proposed land use characteristics

- i) Site is used for parking approximately 200 vehicles.
- ii) The remainder of the site is used for a trading market.
- iii) During the 2010 FIFA Soccer World Cup it was used as a designated viewing site / Fan Zone.
- iv) It is not anticipated that heavy-duty vehicles or military parades showcasing armoured vehicles will regularly utilize the site as was done historically.

5.2.1.3 Quantity and Quality performance requirements

The City of Cape Town's new "Management of Urban Stormwater Impacts" policy sets the minimum requirements that need to be met. These require an 80% reduction in TSS and a 80% reduction in TP.

- i) The conventional design fails to meet the minimum quality requirements. As the sewer network releases directly into the harbour, quantity control is not required
- ii) The 'SuDS' system meets and exceeds all the requirements set by the City.

5.2.1.4 Amenity and Environmental requirements

After the upgrading the site amenity was generally enhanced. The site provides casual parking, daily markets and a place for civic events and demonstrations.

5.2.2 SuDS Design overview

The site has been redeveloped with a section of permeable paving that collects and manages runoff from a much larger tributary area as shown in Figure 5-10. The paving is graded to ensure all the runoff is conveyed to an infiltrated into the permeable paving.

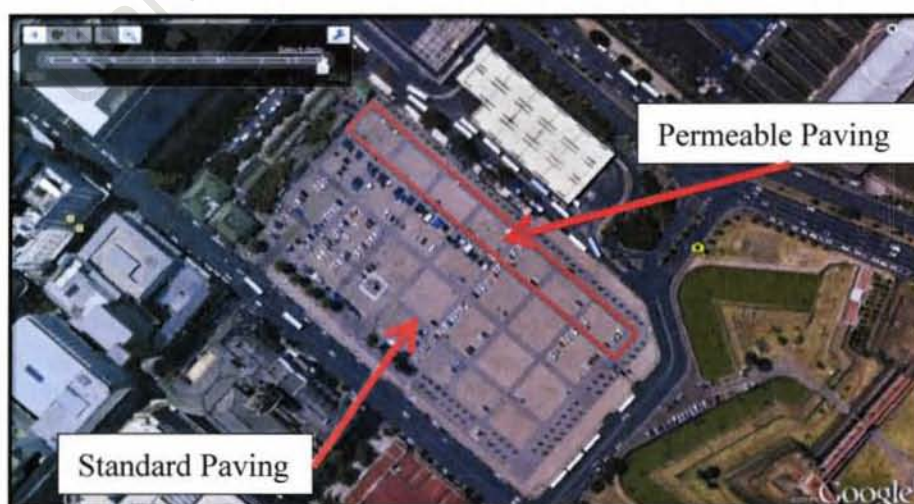


Figure 5-10: Grand Parade Overview (Google, 2011)

Figure 5-10: Grand Parade Overview (Google, 2011)

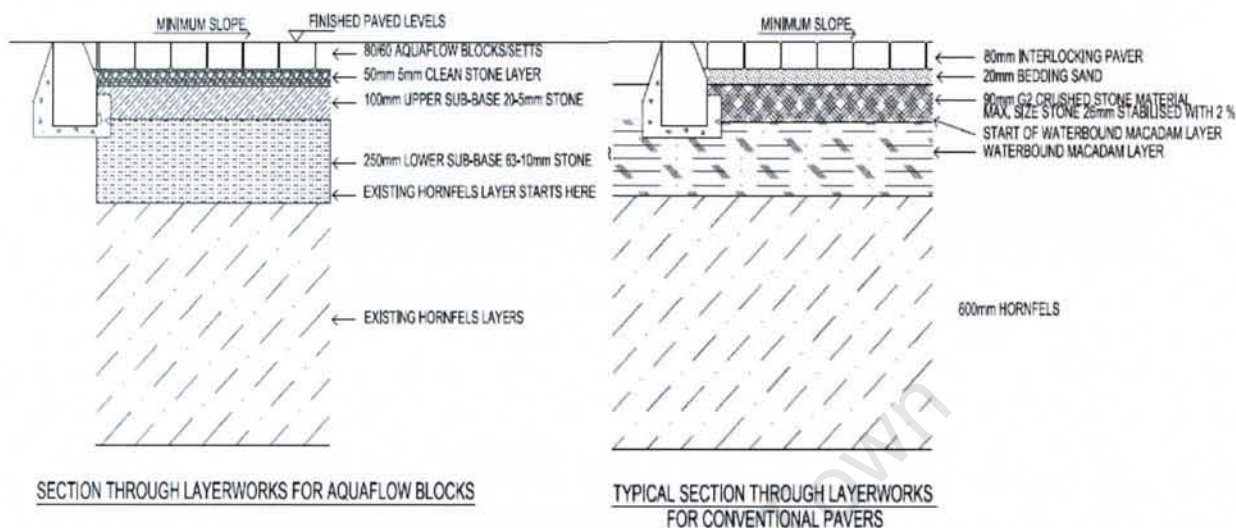


Figure 5-11: PCBP Layer Works (Iliso, 2010)

5.2.3 Conventional Options

5.2.3.1 Concrete Block Paving vs. Asphalt

The site could have been rehabilitated by overlaying the asphalt with a 40mm asphalt layer that would have been significantly cheaper than removing the existing asphalt and replacing it. This analysis assumes that the pavement had reached the end of its design expected useful life and could not be rehabilitated again. As such, the surface had deteriorated to such an extent that it needed replacing. This would leave two options. The first option would be to replace it with a new asphalt surface; the second would be to lay conventional concrete block paving. Studies conducted by the Concrete Manufacturers Association (CMA, 2009) indicate that CBP would in most cases be financially the best choice (CMA, 2009). This is clearly evident in Figure 5-12.

This section assumes the site was to be developed using a conventional approach to stormwater management. The design would entail the removal of the current asphalt surface, compacting and laying of CB over the entire area. The current drainage system would be used in its entirety to drain the site.

There are a number of additional advantages to CBP, in that it may easily be repaired and has a more aesthetically pleasing appearance. It would therefore seem reasonable to conclude that the use of CBP would be optimal for upgrading the Grand Parade using a conventional approach. General layer works are shown in Figure 5-13.

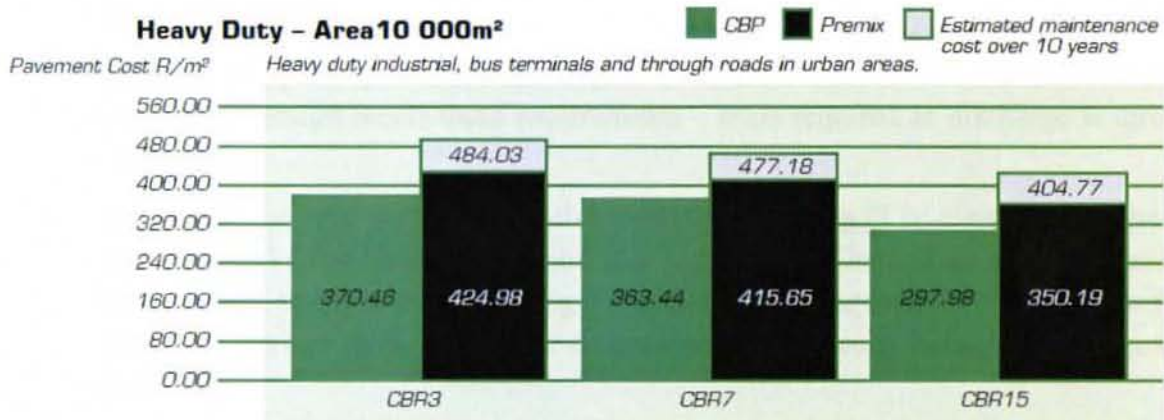


Figure 5-12: CBP vs. Premix Asphalt (CMA, 2009)

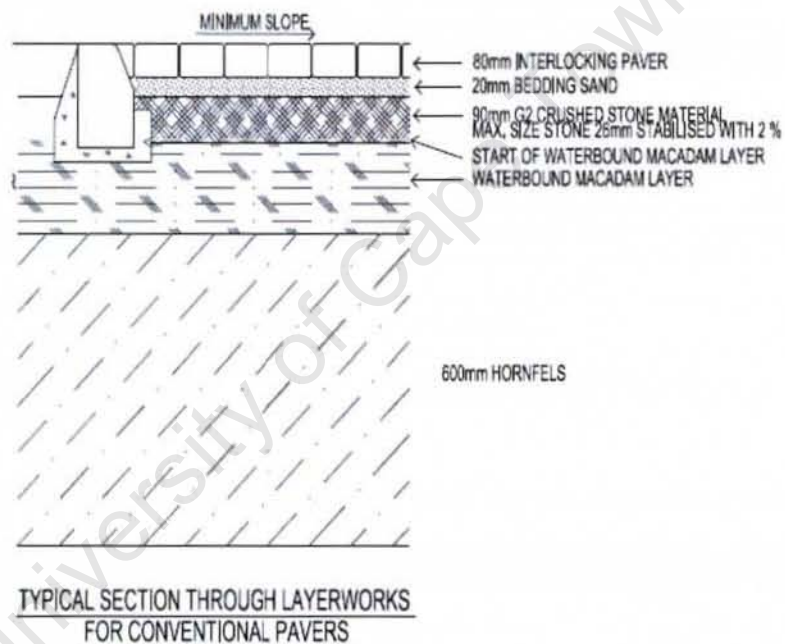


Figure 5-13: Conventional Layer Works (based on Iliso, 2010)

5.2.3.2 Damage Avoidance Cost

The SuDS design ensures the City of Cape Town's stormwater guidelines are met. It is important however to note Figure 5-8, which shows that the conventional system would discharge directly into the harbour. According to SuDS principles, it would therefore not be necessary to consider quantity management. Quality and Amenity remain important. The DAC for the site will therefore be based on the following criteria:

- i) Treatment of the WQv as stipulated by the City of Cape Town using the SA SCS Type 1 storm distribution
- ii) The costs of quantity control for larger RI storms will not be considered as the conventional design meets these requirements – none required as discharge is directly into the ocean.
- iii) The value of the land required for such a treatment facility **will** be considered as the site falls in Central Cape Town where land is at a premium. There is no available land on site. The ‘lost utility’ i.e. no parking or trading on the aqua flow of the Aqua flow (permeable paving) strip, will not be considered as it is clearly being used for parking and trading.

Table 5-7: DAC Parameters

DAC Parameter	Value	Reason
Water Quality Storm Depth (mm/24hrs)	30	½ yr. 24 hr. storm depth
Quantity Control Storm Depth (mm/24hrs)	30	No need to consider quantity control
Lag Time DAC (default 6 minutes)	30	Estimated
Discount Rate (%)	4	Used for comparative analysis
Reduction in predevelopment flow for QCv	0	No reduction required
Recharge (as % of WQv)	8	Estimated from Cape Town recharge map
SCS SA Storm Type	1	
Total Area (m ²)	25,000	Total Area
Effective Impervious Area (m ²)	20,000	Effective Impervious Area

Table 5-8: Annualised valuation of DAC for conventional paving

	DAC (R/year)
Treatment	47,500
Land Value	45,500
Total	93,000

It is clear that there would be substantial cost attached to acquiring and managing a facility capable of managing the site’s runoff. It is also worth noting that two thirds of this cost would be due to the need to ‘acquire land’ to develop the site. In line with the model the DAC has been added to the conventional system.

5.2.4 Life Cycle Costing

Capital Costs were based on the original payment certificates, which were adjusted to October 2010. This was done to ensure that the construction costs were at the same base date as those of the operating and maintenance costs.

Consultant fees (10%), Preliminaries and General (15%), Contingencies (10%) etc. were all estimated as a percent of the cost. These were applied uniformly between designs. The costs considered did not cover all aspects of the redevelopment, only those common to either the conventional or SuDS designs thereby ensuring a 'fair and equivalent' analysis i.e. the following were considered:

- i) Layer works & Surfacing
- ii) Catch pits, grid inlets etc.
- iii) Kerbs & Gutters.

The following were not considered:

- i) Landscaping (such as trees) as these did not perform stormwater functions. i.e. they were not designed to, nor will they function to collect and manage stormwater as a planted catch pit;
- ii) Kerb and channelling running alongside the roads surrounding the Grand Parade, as these form part of the roads drainage system and have no impact on draining the Grand Parade. Additionally the costs would be equal in both designs and so an error in this assumption would be offset; and
- iii) Architectural features and developments i.e. the special work done around the statues etc. was not considered as this would be common to both designs and they perform no stormwater management functions.

Operating and maintenance costs were derived from the fact sheets and focused on the difference between the systems. These consider:

- i) Operation & Maintenance of manholes, catch pits and sewers
- ii) Operation & Maintenance of the permeable paving.

The following were costs were not considered:

- i) Establishment of the trees and maintenance of the trees as they provide no stormwater management function
- ii) Daily sweeping of the market area as this is the same for both designs and is a solid waste management responsibility.

To demonstrate the use of the SEM for this example an analysis has been undertaken using an 4% discount rate. This would normally be varied to determine the sensitivity of the results. The designs are expected to last for 20 years, at which stage they would need to be rehabilitated.

Table 5-9: Analysis Scenarios

Scenario	Description
Low	Low maintenance according to fact sheets over life cycle 20 years
Medium	Medium maintenance according to fact sheets over life cycle 20 years
High	High maintenance according to fact sheets over life cycle of 20 years

5.2.5 Results

The results may be viewed for each design separately, but of real interest for this case study is the comparison of the two systems. The results shown below in Figure 5-14 to Figure 5-16 demonstrate the SEM's ability to compare two systems and present the results in an accessible manner.

Concrete block paving (CBP) and Permeable CBP (PCBP) require minimal regular maintenance other than infrequent sweeping and fixing of any broken bricks. Figure 5-14 however indicates that the PCBP requires more maintenance than CBP.

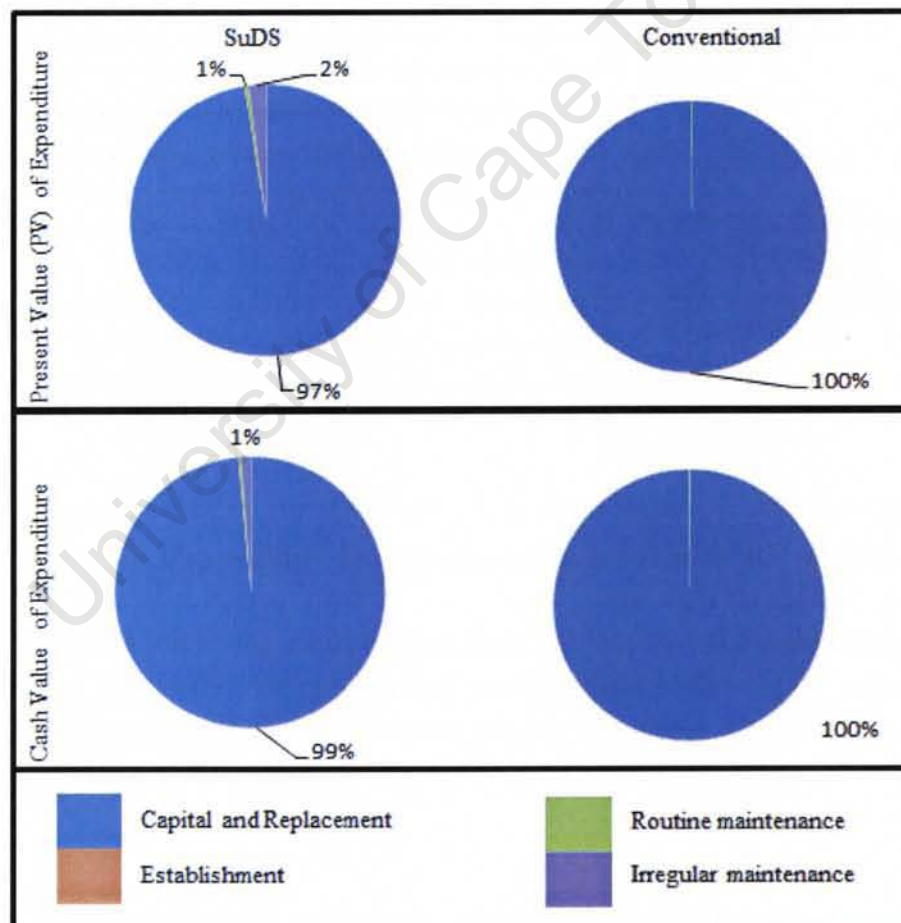


Figure 5-14: Comparative cash expenditure for permeable and conventional paving

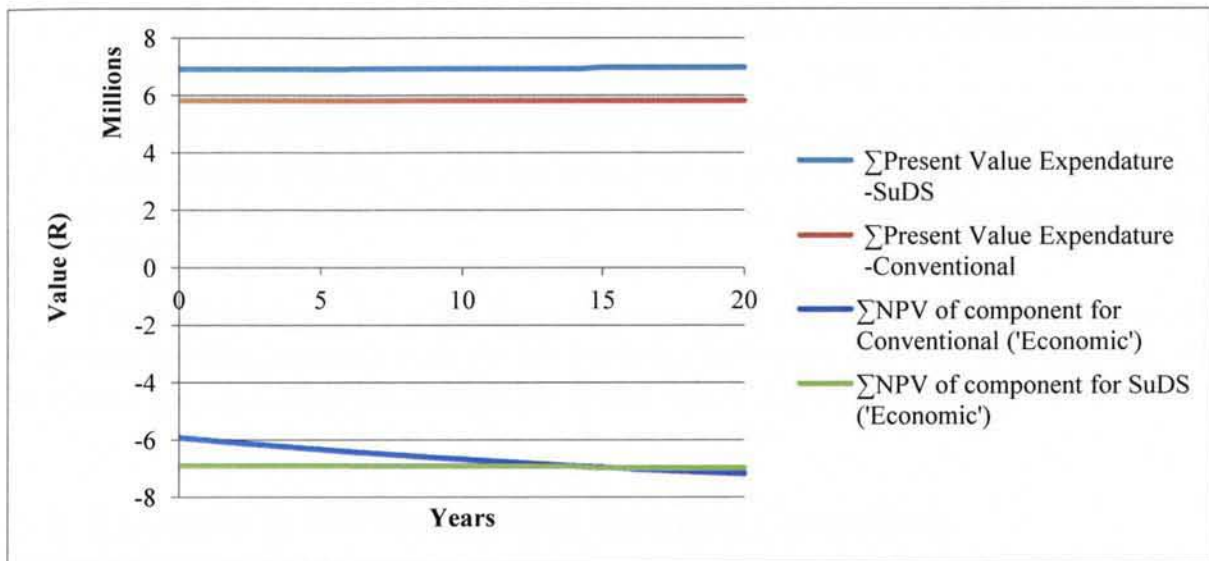


Figure 5-15: Present Value (PV) and Net PV (benefits - costs) of expenditure of Grand Parade stormwater system

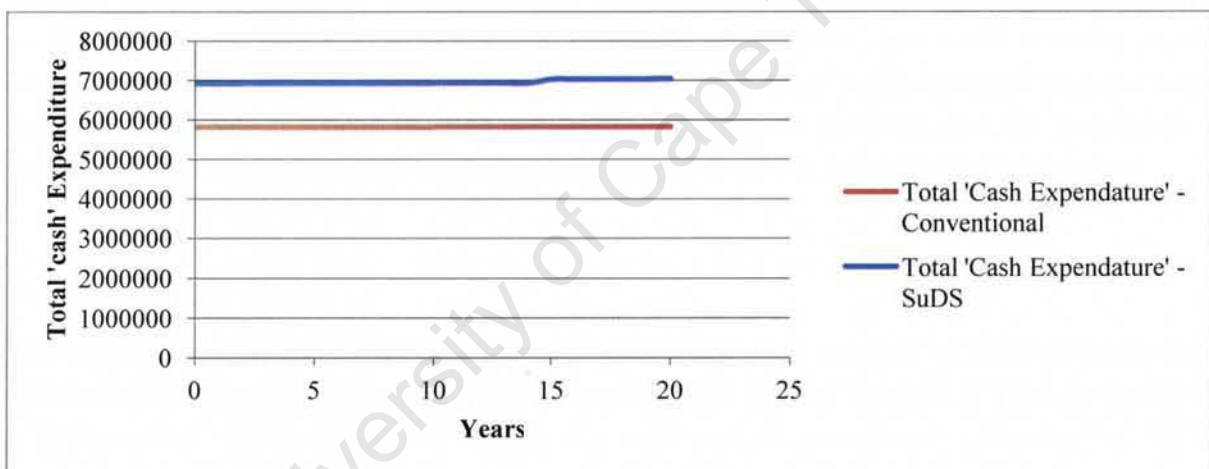


Figure 5-16: Cash Expenditure breakdown of Grand Parade stormwater system

It is worth noting that while the capital costs form the bulk of the expenditure for both designs, with the permeable paving system having marginally higher operating and maintenance costs. The benefit of the permeable paving is realised in the NPV graph where the conventional system continues to pay the DAC. At 15 years the NPV of the systems are equivalent.

5.2.6 Conclusions

The model has been successfully applied to considering the economics of the development of a large public open space using permeable paving. This example has demonstrated the SEM in a situation where land value should be considered when applying the DAC tool to calculate

the value of EGS. While limited technologies were used, this example has also demonstrated the simplicity and the usefulness of the comparative analysis charts.

The calculation of the DAC clearly indicates that significant resources would be required to acquire and manage a facility to treat stormwater where permeable paving was not used. The significant 'land cost' highlights the difficulties that would be faced in finding suitable land in the CBD.

The results indicate that while the permeable paving may have a higher capital cost the regulating services provided over the life cycle are extremely valuable. It is clear that the permeable paving design has a number of benefits over a 'conventional design'.

5.3 Example 3: Mitchells Plain Hospital Case Study

5.3.1 Introduction

The following case study is based on a site currently under development by the Western Cape Provincial Government. Since the site was used as a case study the design has undergone a number of minor revisions. For biodiversity reasons, the selection of vegetation was limited to those found on site. This analysis was based on typical rates, and was not based on the vegetation chosen for the site as these were in the process of being selected and the costs estimated. The site has been used to demonstrate the use of the SEM and not to conduct a comprehensive economic study, which would require expenses to be locally determined

5.3.2 Context

The original stormwater design for this site was based on a network of underground pipes which transferred all runoff to an on-line detention pond. Due to changes in local by-laws and a 'progressive' design team, the design was reviewed to incorporate a number of SuDS technologies. The 'new SuDS design' incorporates aspects of conventional design to drain critical areas where quantity control is of utmost importance. The runoff is then treated through a combination of buffers, infiltration ponds, swales and bio-retention areas. The basic designs were developed outside of the research group. This is advantageous as it reduces any potential bias regarding the results of this case study. It further adds a degree of confidence to all the case studies.

5.3.2.1 Site & Catchment characteristics

- i) The site is situated in Mitchell's Plain, Cape Town
- ii) It is a previously undeveloped, greenfield site,
- iii) A 750mm municipal stormwater pipe runs along the western side of the site (see Figure 5-17 in red)
- iv) The site is flat / undulating (DWA, 2010)

- v) The predominant soil type is “Greyish, sandy excessively drained soil” (City of Cape Town - GIS, 2009)
- vi) The ground water table is expected to lie over 3m below surface level (DWA, 2010).



Figure 5-17: Site prior to and during development (Google Earth, 2011)

5.3.2.2 Quantity and Quality performance requirements

The City of Cape Town’s new “Management of Urban Stormwater Impacts” (CSRM, 2009) policy sets the minimum requirements that need to be met for the SuDS design. The conventional design fails to do so and thus the analysis will account for EGS provided by the SuDS system by using the DAC tool.

5.3.2.3 Amenity and Environmental requirements

There are no environmental or amenity requirements, although there is to be extensive landscaping of the outside areas for both designs.

5.3.2.4 Legal obligations and requirements

Further than the City of Cape Town's requirements, there are no further site specific legal obligations or requirements.

5.3.3 Conventional Design

The design, shown in Appendix A-1, as with all 'conventional' designs focused on quantity management. All the runoff from the hospital site was efficiently collected and drained to a single detention pond which was designed to detain the runoff and release it in a controlled manner. While there was potential for some of the runoff to infiltrate while it was being detained, this was not considered to be the primary disposal method, and the majority will have entered into the municipal system (Mostert, 2010).

The site is expected to have extensive landscaping. As is evident the conventional design did not attempt to exploit this to manage the stormwater, instead all runoff was collected and detained in a single detention pond before it was released to the municipal system.

The design ensures that up to the 50 year RI is detained on site by an inline detention pond. The outlet however is a single stage outlet at the base of the detention pond and thus will offer very limited detention for small RI/frequent storms. The treatment offered, by what should be considered a quantity control pond and not a detention pond, is negligible (3% TSS, 19% TP (Debo & Reese, 2003)). The DAC for the site will therefore be based on the following criteria:

- i) Treatment of the WQv as stipulated by the City of Cape Town using the SA SCS Type 1 storm distribution
- ii) The costs of quantity control for larger RI storms will not be considered as the conventional design meets these requirements.
- iii) The value of the land required for such a treatment facility will not be considered as the site has sufficient open land on which such a facility could be installed.

5.3.4 SuDS Design

The SuDS design used for this analysis has been subsequently amended. Amendments included the infiltration ponds being landscaped using indigenous plants, as per the contract and shaped on site. The concrete block swale was amended to form part of the network of infiltration ponds. The selection of the original SuDS design for analysis is a pragmatic decision made in order to simply demonstrate the model as opposed to focusing on the technical aspects of the design. The design combines elements of SuDS and conventional approaches to stormwater management. The SuDS design, as shown in Appendix A-2, is comprised of seven infiltration ponds, treatment swales and filter strips (Mostert, 2010).

A review of the 'SuDS' design resulted in a number of minor technical issues being noted. The following four issues were identified and dealt with as described below:

- i) There is no indication of erosion management, flow spreading or sediment management prior to the basins. The Klitzner (2011) does suggest that calcrete on site would be reused in to perform these functions. Without some form of erosion management the result will likely be long term failure of the ponds as sediment will collect in the ponds resulting in them becoming clogged. In order to better manage the inflows from the sewer network a flow spreader was added to the cost of the design at each inlet head wall. Figure 5-18, is an example of such a flow spreader constructed out of gabions.
- ii) The "enhanced swales" as defined by the design team are not designed according to the definition of an enhanced swale. They should be termed bio-retention areas or treatment swales as they are designed to retard the water flow and remove nutrients. For the cost model these areas were treated as standard bio retention areas.
- iii) The design requires grass block channels. The channel could easily be served by a standard grass channel that would lead to large cost savings.
- iv) The ponds have been termed "retention ponds" by the design team; however they act as infiltration ponds/basins disposing of the runoff through infiltration and do not maintain a permanent pool of water (Debo & Reese, 2003; Jefferies, 2005). This is significant as the groundwater level impacts on the efficiency of the ponds. The level of the ground water is expected to be sufficient (i.e. >1m below the bottom of all the basins during winter).



Figure 5-18: Flow Spreader (Berwick, 2011)

5.3.5 Life Cycle Costing

Capital costs were based on the original payment certificates, which were adjusted to October 2010. SuDS component costs were based on the 'Fact Sheets' in Appendix F. This was done to ensure that the construction costs were at the same base date as those of the operating and maintenance costs.

The costs considered did not cover all aspects of the redevelopment, only those common to either the conventional or SuDS designs i.e. the following were considered:

- i) Conduits
- ii) Catch pits, grid inlets etc.
- iii) Kerbs & Gutters.
- iv) Swales
- v) Buffer Strips
- vi) Bio retention Areas
- vii) Infiltration Pond
- viii) Detention Ponds

The following were not considered:

- i) Landscaping not impacting on stormwater management – as the site was to be landscaped, and these should not be considered stormwater costs.
- ii) Calcite (Rocky) swales – these were treated as bio retention areas, as the rocky swales may develop maintenance problems.

Operating and maintenance costs were derived from the fact sheets and focused on the difference between the systems. These consider:

- i) Operation and maintenance of manholes, catch pits and sewers
- ii) Operation and maintenance of the SuDS options

The Expected Useful Lives of the different SuDS options/ technologies were estimated based on those provided in the Fact sheets. Due to the range of EUL's the analysis is conducted over 100 years.

To demonstrate the use of the SEM for this example an analysis has been undertaken using an 4% discount rate. This would normally be varied to determine the sensitivity of the results.

Table 5-10: Analysis Scenarios

Scenario	Description
Low	Low maintenance according to fact sheets over life cycle 100 years
Medium	Medium maintenance according to fact sheets over life cycle 100 years
High	High maintenance according to fact sheets over life cycle of 100 years

5.3.6 Results

The results for the economic analysis are presented in Figures 5-19 to 5-22. Figure 5-19 and 5-20 highlights that the SuDS design will require significant additional expenditure over the first few years after construction to ensure that the requisite vegetation is properly established. It is therefore important that funds be set aside over and above that for simply constructing the designs. It is also interesting to note that the percentage breakdown of expenditure (when establishment costs are included as part of capital) are the same. This is likely due to the use of conventional elements in this design.

Figure 5-19 clearly demonstrate the cash flow, present value and net present values of the designs and may be used to inform those responsible for making the decisions about the financial commitments required for each design.

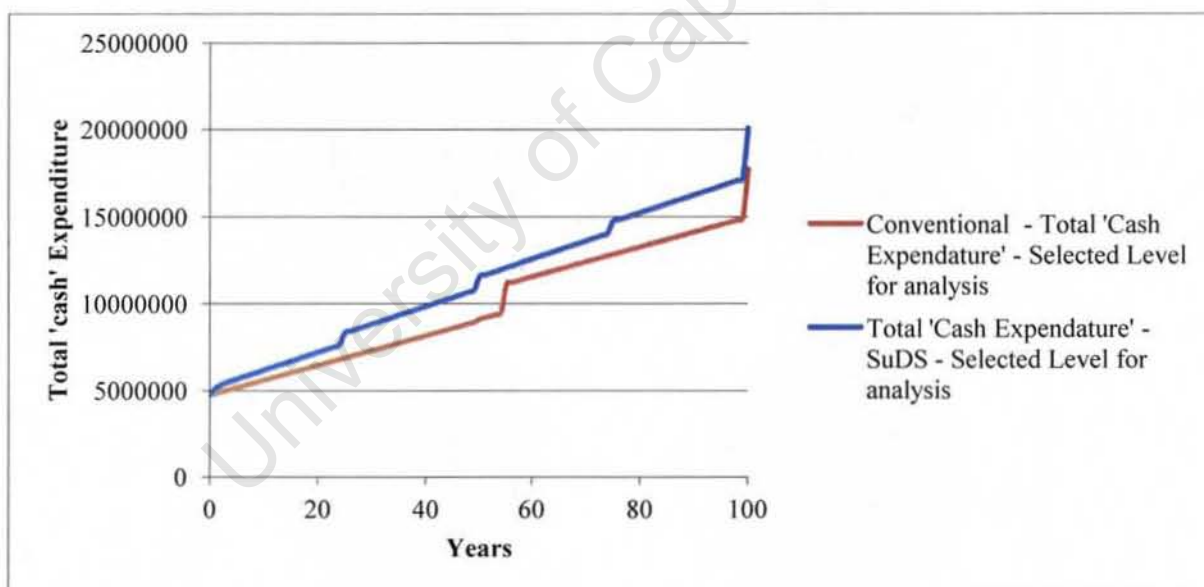


Figure 5-19: Σ Cash Flow of hospital stormwater system

Figure 5-20 highlights that while the present value is relatively similar, once all costs and benefits are considered, there is a significant difference. In this case the additional costs considered were: the cost of making a connection to the municipal stormwater system (R 3,000,000.00) and the DAC. No benefits for either system were considered as no local data was available. It is now possible to undertake a 'fair and equivalent' economic analysis as both systems are being compared on an equal basis.

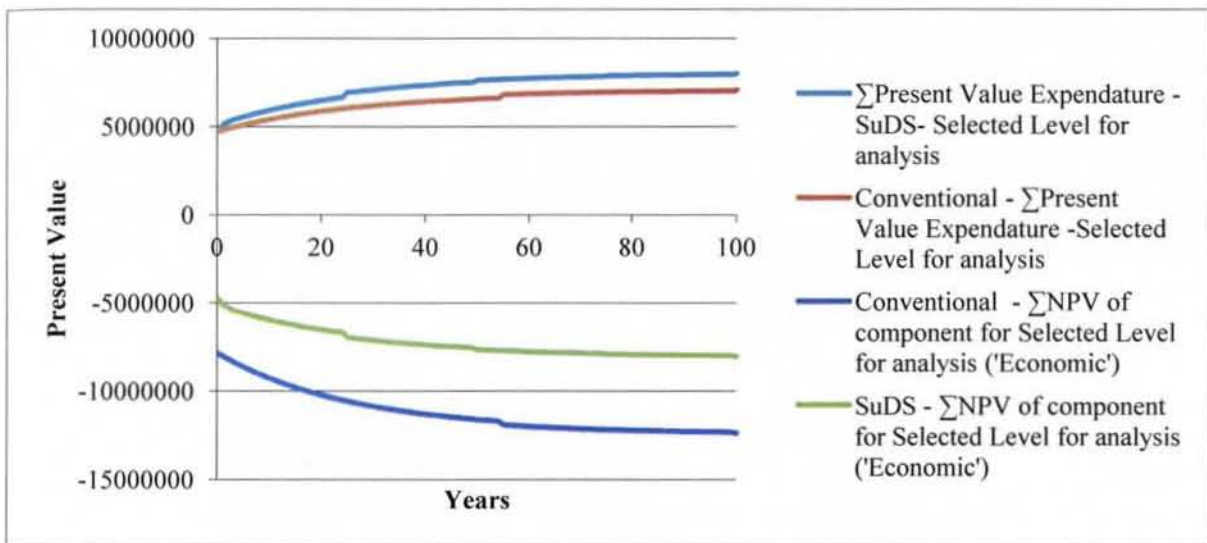


Figure 5-20 : Present Value (PV) and Net PV (benefits - costs) of hospital stormwater system

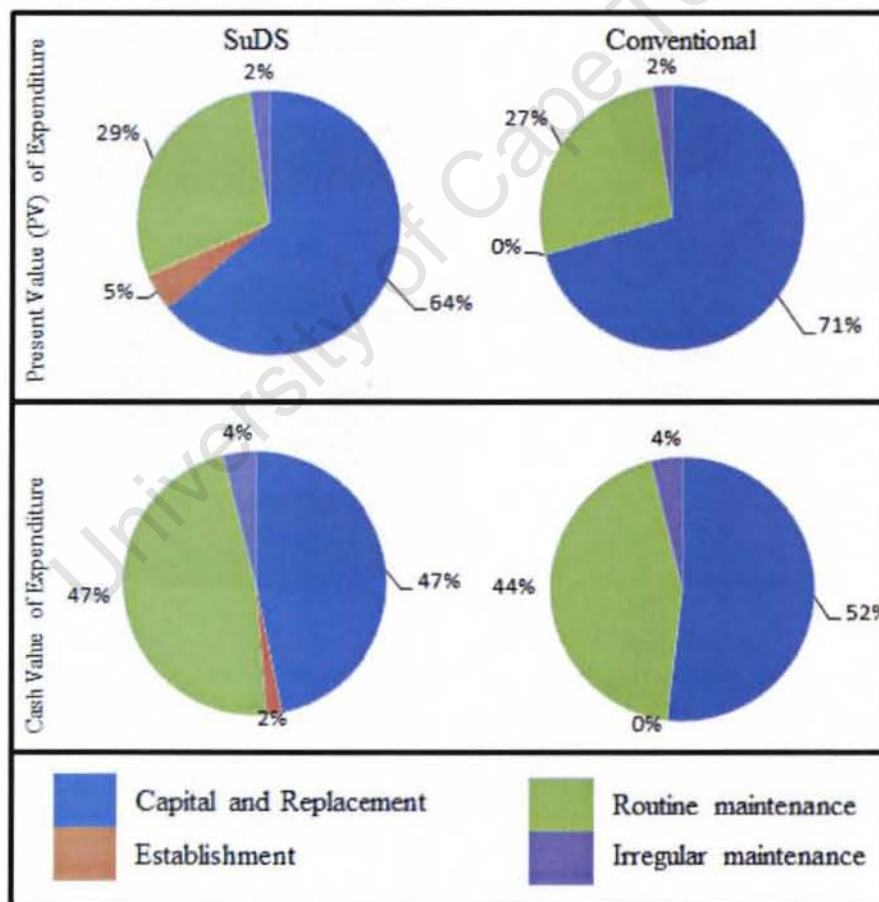


Figure 5-21: Expenditure breakdown for Medium level of Maintenance of hospital stormwater system

Figure 5-22 demonstrates the SuDS 'Cost Treatment Train'. It clearly highlights that the major part of the costs are on technologies on a local scale, and that there are very few source and regional controls. This may indicate that the design should be reconsidered, and a greater emphasis be placed on source controls – in this case Green Roofs. However it could be considered appropriate as there may be a lack of capacity to manage the source controls optimally, hence the need for greater reliance on local controls. The SuDS 'Cost Treatment Train' may be used to ensure that the design is appropriate for the context in which it must operate.

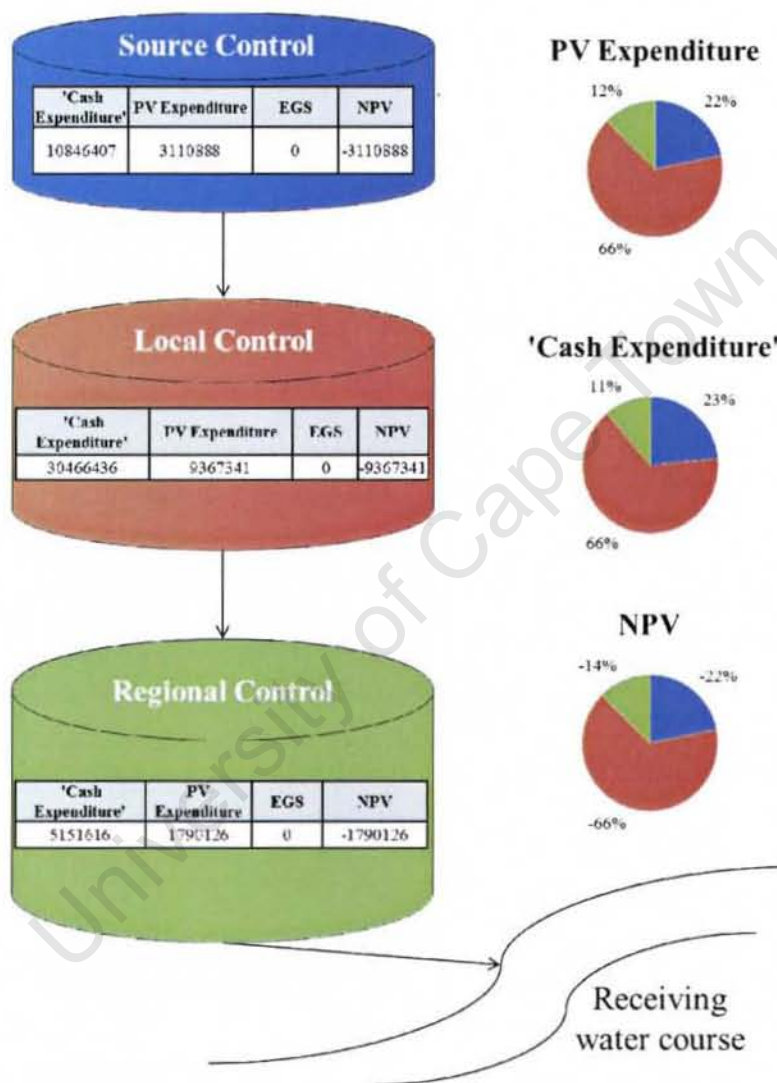


Figure 5-22: SuDS 'Cost Treatment Train' of hospital stormwater system

5.3.7 Conclusions

This example has demonstrated the application of the SEM for sites with a range of technologies, both SuDS and Conventional, as is the case for local and regional case studies. The SuDS 'Cost treatment train' does indicate that there are limited source controls that could impact on the survivability of the treatment. Were the SEM to be used as part of the design it

would suggest a need to consider the need for more source controls such as those suggested in Section 5.3.4. Additionally the use of the various outputs are useful in understanding the financial and economic implications of each design and will allow a user, and stakeholders to better understand which design is most appropriate for their development.

6. Conclusions

The Simple Economic Model (SEM) was developed to address the weaknesses that were identified in the models reviewed. The SEM and supplies a simple, user friendly, and accessible model that will allow stakeholders to undertake the increasingly necessary analysis of the economics of different approaches to stormwater management. The SEM's four primary aims were to:

- i) Establish the life cycle costs of alternative drainage designs;
- ii) Account for the differences in environmental impacts on an 'equivalent and fair basis;
- iii) Provide a simple method that may be applied to different sites within South Africa; and
- iv) Present results in a manner that is accessible and understandable to the stakeholders.

Table 6-1: Aims of the Simple Economic Model

Aim	Requirements	Achieved
Establish the life cycle costs of alternative drainage designs.	Calculate LCC for SuDS and conventional Systems using the same approach, making allowance for the differences in each system.	Yes
	Allow for the aggregation and disaggregation of results, in line with SuDS principles.	Yes
	Allow for the entering of different maintenance scenarios, and sensitivity analysis using the different scenarios	Yes
	Allow for sensitivity analysis by varying the discount rate	Yes
Account for the differences in environmental impacts on an 'equivalent and fair basis.'	Provide a method for estimating the value of Environmental goods & services that may be used throughout South Africa	Partly
	Account for the different life cycles of different drainage technologies	Yes
Provide a simple method that may be applied to different sites within South Africa.	Provide a model that is user friendly, and could be used by stakeholders with different competencies	Cannot be assessed yet.
	Provide all basic data (costs, maintenance frequencies etc.) to allow users to be able to conduct quick analyses.	Partly.
	Provide a model which may be used on projects of different scales.	Yes
Present results in a manner that is accessible and understandable to the stakeholders.	Allow for the aggregation and disaggregation of costing data, in line with SuDS principles to allow users at different scales to identify the costs attributable to them.	Yes
	Present results both in detailed tables and simplified but accessible graphics.	Yes
	Are 'usable' by any person potentially involved in the design or management of SuDS.	Cannot be assessed yet.

As outlined in Table 6-1 the requirements that were initially set to determine success have all been met in part – at this stage cannot be fully assessed – or in whole.

It is important to recognise the limitations of the SEM. Firstly the SEM deals with risk by assuming both designs being compared are designed for the same recurrence interval, while acknowledging that if a SuDS system is not maintained, it has a higher risk of failure. Secondly, the Damage Avoidance Cost tool only considers the quantity and quality management 'provided' by a 'reliable' conventional treatment facility. There is no way of ensuring that both the SuDS and conventional systems would operate to the same efficiency or would be managed in an equivalent manner in any specific environment.

The three examples have demonstrated the SEM's functionality and its ability to present results that are accessible to a wide range of stakeholders who do not have the technical 'know how' or understanding to undertake such an analysis.

Most importantly the SEM demonstrates that it is possible to take account of ecosystem goods and services. This may therefore be the model's greatest value in that it dispels the 'myth' that it is not possible or too cumbersome to value ecosystem goods and services. The valuation of ecosystem goods and service will inform design as the true value of these essentially free goods/services becomes apparent. Where a design team may feel that they are able to prove that there is a lower cost alternative, they would be free to use this in the analysis. They would however need to prove that it met the criteria laid out throughout this document. The requirements in Table 6-1 cannot as yet be assessed objectively. Time will tell how effective the SEM model is in enabling practitioners to consider alternative drainage systems in a fair and equivalent manner.

7. Recommendations for further research

There is a worldwide shift towards the implementation of what is termed Sustainable urban Drainage Systems / Sustainable Drainage Systems (SuDS). A barrier common to the wider use of SuDS in South Africa is uncertainty regarding the total cost of implementation. While this research has highlighted a number of valuable resources and has presented an easy to use model (the SEM) that undertakes the menial work of conducting an economic analysis, it has not fully addressed the uncertainty regarding the costs of implementation. This uncertainty will only be addressed as experience is developed locally and costing data becomes available. If the foundations are put in place now, it will be possible to ensure that this information becomes available timeously. The following research needs to be undertaken:

- Further research is required into the horticultural aspects of stormwater management. This is a vital aspect of research as it could potentially impact on the maintenance requirements of a system as well as the goods and services which might be derived from such a system.
- Further research is needed to consider the local requirements of SuDS for the different levels of maintenance. It needs to consider the differences based on regional and climatic factors (e.g. malaria areas may require different maintenance regimes). The development of an online SuDS database that captures information for different SuDS options from around South Africa would provide the basis for this research. The following information would be need to be collected:
 - Development costs
 - Basic design (to allow the analysis of costs related to design)
 - Maintenance frequencies and costs
 - Life cycle of different SuDS Options
 - Location

While this is a relatively simple task, in the future at five year intervals the data could be analysed and the results published. This would go a long way towards informing and reducing the uncertainty that negatively impacts on and acts as a barrier to the wider use of SuDS locally.

- While maintenance and life cycle costing is a significant aspect of the economics of SuDS, it is also vital that future research focus on better accounting for the environmental goods and services provided by SuDS systems. While the Damage Avoidance Cost tool has gone some way towards presenting a quick, simple method for undertaking such an analysis, it only accounts for quantity control and quality treatment. Amenity and biodiversity are equally important aspects that should be considered, yet are incredibly difficult to account for. As more projects implement SuDS it will be possible to collect adequate data for such analyses.
- The Damage Avoidance Cost considers the quantity and quality management 'provided' by a 'reliable' conventional treatment facility. It is necessary that research

be undertaken into the efficiency of the treatment offered by SuDS locally to objectively demonstrate that SuDS is in fact treating stormwater to an equivalent degree

- A question that arose during the presentation of the research nationally was surrounding risk. The SEM deals with risk by assuming both designs being compared are designed for the same recurrence interval, while acknowledging that if a SuDS system is not maintained, it has a higher risk of failure. Butterworth *et al.*,(2011) suggested the implementation of SuDS to better manage the risks related to climate change. Further research needs to look into how SuDS manage, mitigate or increase risk and how this may be accounted for.

With SuDS being in its infancy in South Africa it will be difficult to make long term findings in any of these areas. It is though possible to begin the necessary research. It is vital that the databases and tools for collecting the relevant data are put in place and managed so that in time it will be possible to analyse this data and provide reliable, relevant and accurate data for local stakeholders based on local conditions.

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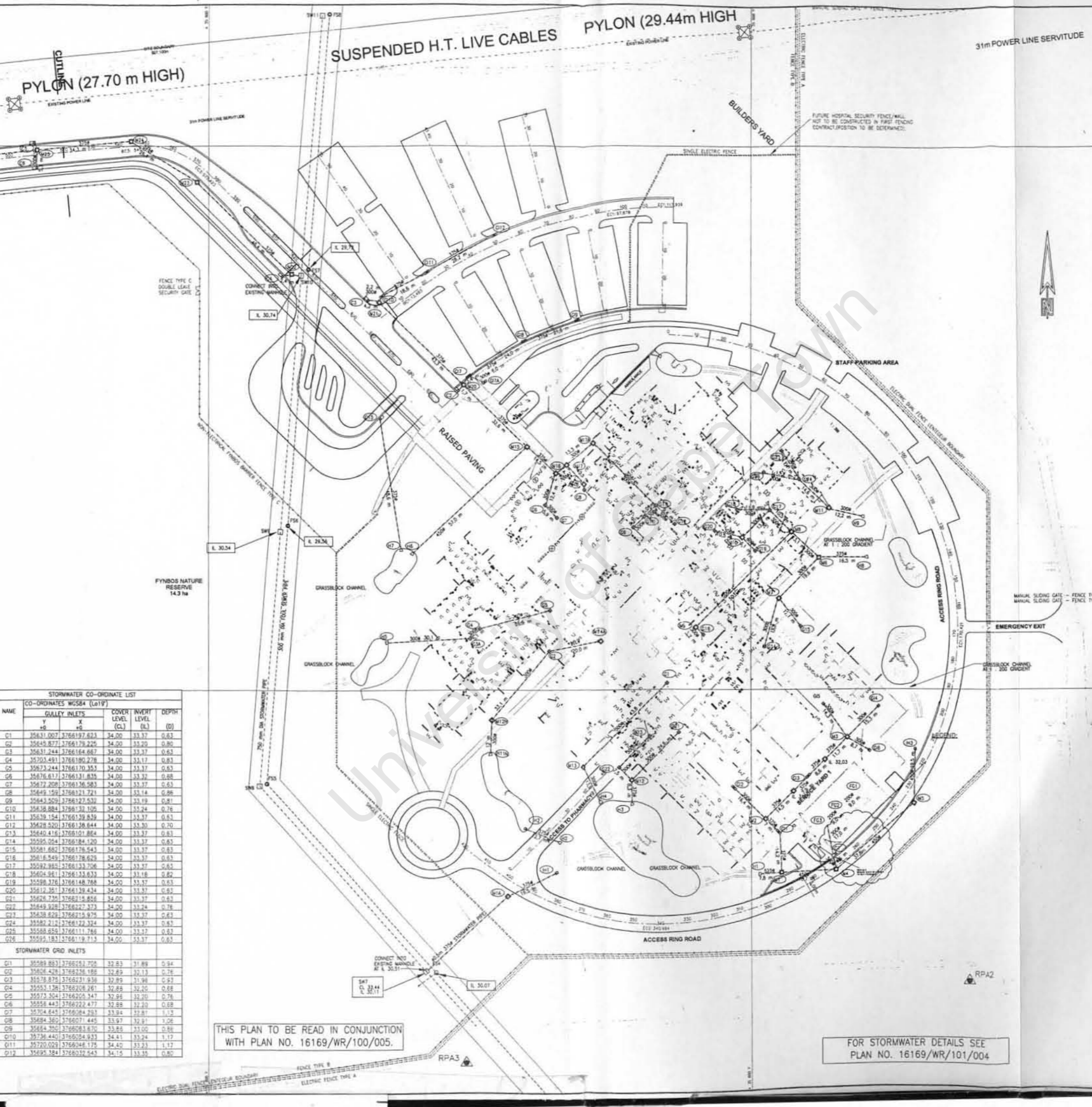
Appendix A

Mitchells Plain District Hospital Stormwater designs

1. Conventional Design
2. SuDS Design

University of Cape Town

CONTINUED ON DRAWING
16169/WR/100/005



STORMWATER CO-ORDINATE LIST

NAME	CO-ORDINATES WGS84 (Lat/L)	COVER LEVEL (CL)	INVERT LEVEL (IL)	DEPTH (D)
M1	35712.421 3766312.173	33.30	30.51	2.79
M2	35588.805 3766267.807	33.38	31.83	1.53
M3	35594.700 3766247.782	32.85	31.91	0.94
M4	35584.487 3766217.633	33.00	32.08	0.92
M5	35588.884 3766266.668	33.15	31.87	1.28
M6	35539.915 3766238.095	33.35	31.95	1.40
M7	35574.857 3766151.318	34.00	32.84	1.16
M8	35589.825 3766186.184	34.00	33.22	0.78
M9	35585.026 3766141.771	34.00	33.04	0.96
M10	35619.148 3766175.690	34.00	33.32	0.68
M11	35603.178 3766143.853	34.00	33.30	0.70
M12	35571.159 3766132.989	34.00	33.25	0.75
M13	35644.564 3766233.880	34.00	33.09	0.91
M14	35662.098 3766228.395	34.00	33.24	0.76
M15	35697.478 3766174.414	34.00	33.22	0.78
M16	35681.013 3766112.365	34.00	32.72	1.28
M17	35672.579 3766120.136	34.00	32.82	1.18
M18	35659.549 3766111.262	34.00	33.03	0.97
M19	35635.045 3766135.696	34.00	33.30	0.70
M20	35647.354 3766094.784	34.00	33.20	0.80
M21	35706.532 3766087.512	33.94	32.81	1.13
M22	35737.539 3766057.225	34.41	33.15	1.26
M23	35789.795 3766047.622	34.37	31.91	2.56
M24	35804.219 3766015.157	34.82	32.11	2.71
M25	35828.559 3765998.231	34.82	32.25	2.57
M26	35862.811 3766001.563	34.74	32.36	1.88
M27	35942.495 3766009.591	34.00	32.48	1.52
M28	36020.512 3766017.297	34.23	33.00	1.23
M29	36189.896 3766211.736	34.18	33.18	1.02
M30	36124.459 3766183.681	34.04	33.00	1.05
M31	36116.306 3766157.086	34.00	32.90	1.10
M32	36147.225 3766112.950	34.00	32.53	1.47

STORMWATER CO-ORDINATE LIST

NAME	CO-ORDINATES WGS84 (Lat/L)	COVER LEVEL (CL)	INVERT LEVEL (IL)	DEPTH (D)
G1	35831.007 3766197.823	34.00	33.37	0.63
G2	35649.877 3766179.225	34.00	33.20	0.80
G3	35631.244 3766164.667	34.00	33.37	0.63
G4	35703.491 3766190.278	34.00	33.17	0.83
G5	35873.244 3766170.353	34.00	33.37	0.63
G6	35876.617 3766131.835	34.00	33.32	0.68
G7	35872.208 3766136.983	34.00	33.37	0.63
G8	35849.159 3766121.721	34.00	33.14	0.86
G9	35843.509 3766127.537	34.00	33.19	0.81
G10	35838.884 3766132.109	34.00	33.24	0.76
G11	35839.154 3766139.839	34.00	33.37	0.63
G12	35828.920 3766138.844	34.00	33.30	0.70
G13	35840.418 3766101.884	34.00	33.37	0.63
G14	35856.084 3766184.120	34.00	33.37	0.63
G15	35861.682 3766178.543	34.00	33.37	0.63
G16	35816.549 3766178.623	34.00	33.37	0.63
G17	35892.885 3766133.706	34.00	33.37	0.63
G18	35804.981 3766133.833	34.00	33.18	0.82
G19	35898.376 3766148.768	34.00	33.37	0.63
G20	35812.361 3766139.434	34.00	33.37	0.63
G21	35825.735 3766115.858	34.00	33.37	0.63
G22	35849.928 3766227.373	34.00	33.24	0.76
G23	35838.829 3766215.875	34.00	33.37	0.63
G24	35882.212 3766172.324	34.00	33.37	0.63
G25	35888.656 3766111.766	34.00	33.37	0.63
G26	35899.183 3766119.713	34.00	33.37	0.63

STORMWATER CATCHPITS

NAME	CO-ORDINATES WGS84 (Lat/L)	COVER LEVEL (CL)	INVERT LEVEL (IL)	DEPTH (D)
C1	35569.852 3766261.520	33.75	32.95	0.80
C2	35706.538 3766089.636	33.94	33.10	0.84
C3	35741.715 3766056.378	34.30	33.54	0.76
C4	35773.201 3766047.667	34.53	33.80	0.73
C5	35863.941 3765998.853	34.74	33.44	0.80
C6	35862.991 3766027.959	34.74	33.34	0.90
C7	35943.675 3766026.857	34.00	33.20	0.80
C8	35942.718 3766015.984	34.00	33.10	0.90
C9	36022.461 3766014.892	34.23	33.43	0.80
C10	36021.474 3766023.998	34.23	33.33	0.90
C11	36149.724 3766114.183	34.31	33.51	0.80
C12	36142.406 3766108.590	34.31	33.41	0.90
C13	36116.575 3766177.538	34.05	33.15	0.90
C14	36126.908 3766173.329	34.05	33.15	0.90
C15	36173.144 3766098.989	33.96	33.00	0.96

STORMWATER GRID INLETS

NAME	CO-ORDINATES WGS84 (Lat/L)	COVER LEVEL (CL)	INVERT LEVEL (IL)	DEPTH (D)
I1	35589.883 3766253.729	33.83	31.89	0.94
I2	35606.438 3766236.189	33.89	32.13	0.76
I3	35678.875 3766231.938	33.80	31.98	0.82
I4	35655.138 3766208.267	32.88	32.00	0.88
I5	35673.504 3766205.347	32.96	32.20	0.76
I6	35658.443 3766222.477	32.88	32.20	0.68
I7	35704.645 3766084.283	33.94	32.81	1.13
I8	35684.360 3766071.445	33.97	32.91	1.06
I9	35664.300 3766083.870	33.85	33.00	0.85
I10	35736.440 3766094.933	34.41	33.24	1.17
I11	35720.029 3766046.175	34.40	33.23	1.17
I12	35695.384 3766039.943	34.15	33.35	0.80

THIS PLAN TO BE READ IN CONJUNCTION
WITH PLAN NO. 16169/WR/100/005.

FOR STORMWATER DETAILS SEE
PLAN NO. 16169/WR/101/004

OVERALL PLAN

NOTES:

- THE USE OF TRADE NAMES ON THIS DRAWING SHOULD BE TO INDICATE A STANDARD ACCEPTABLE TO THE DIRECTORATE WORKS AND OTHER AGENCIES MAY BE USED WITH THE PRIOR APPROVAL OF THE DIRECTORATE WORKS.
- ALL DRAWINGS TO BE READ IN CONJUNCTION WITH DETAILS, SCHEDULES, DRAWINGS, CHANGES, INTERNAL ELEVATIONS, ENGINEERS AND OTHER SPECIALIST DRAWINGS.
- ALL WORK DONE AND MATERIALS USED MUST COMPLY WITH THE RELEVANT SECTION OF SOUTH AFRICAN NATIONAL STANDARDS - SAME SAME NUMBER SAME 12500 SPECIFICATIONS AS APPLICABLE UNLESS OTHERWISE STATED.
- MEASUREMENTS MUST BE OBTAINED FROM THE MUNICIPALITY BEFORE ANY WORK IS DONE OUTSIDE THE PROPERTY BOUNDARIES.

MH - MANHOLE T - TEE PIECE
 CP - CATCHPIT B - BEND
 FH - FIRE HYDRANT RE - RODDING EYE
 SV - SLUICE VALVE REL - ROAD EDGE LEVEL

LEGEND

- PROPOSED POUL SLOVER
- FIRE MAIN
- PROPOSED POTABLE WATER
- PROPOSED STORMWATER
- EXISTING SHOWER KEYS WITH CHANNEL
- 800 mm V-CHANNEL
- BARRIER KEYS WITH CHANNEL (CK)
- BARRIER KEYS ONLY (CK)
- TYPE E1 PRECAST CONCRETE EDGING
- ELECTRICAL DUCTS AND DRAWBOX
- TELECOM DUCTS AND DRAWBOX
- COM DATA DUCTS AND DRAWBOX
- 110 mm DIA IRRIGATION SLEEVE

NOTES:

- STORMWATER PIPES SHALL BE INSTALLED AS PER THE MANUFACTURERS RECOMMENDATIONS.
- STORMWATER PIPES UP TO 375 mm DIAMETER INSTALLED UNDER BUILDING FLOOR SHALL BE PE STRUCTURED WALL PIPES WITH SANCTION JOINTS OR BURKAPUR PIPES - 3000 WALL TYPE MANUFACTURED ACCORDING TO SANS 791 SPECIFICATION AND SHALL HAVE INTEGRAL SOCKETS.
- PIPES FOR USE UNDER ROADS AND PARKING AREAS SHALL BE CLASS 100 D REINFORCED CONCRETE PIPES COMPLYING WITH SANS (SABS) 817 WITH RUBBER RING JOINTS.
- MANHOLES SHALL BE CONSTRUCTED OUT OF STANDARD STOCK BRICKS WITH SMOOTH FINISHING AND A BAGGED WALL FINISH UP TO A DEPTH OF 1.5m.
- PRE-CAST MANHOLE SECTIONS SHALL COMPLY WITH SANS 817-1989 SPECIFICATION FOR CLASS B CONCRETE PIPES MAY BE USED TO EXTEND THE MANHOLE ABOVE 1.5m DEPTH TO THE FULL DEPTH REQUIRED AND SHALL HAVE SEALED INTERLOCKING JOINTS.
- PRE-CAST CONCRETE MANHOLE COVER SLABS SHALL COMPLY WITH SANS 1294-1981 AND THE JOINT BETWEEN THE MANHOLE SECTIONS AND THE COVER SLAB SHALL BE SEALED WATER TIGHT.
- PIPE TRENCHES SHALL COMPLY WITH SANS 12000B SPECIFICATION AND PIPES SHALL BE Laid IN A BEDDING CHANNEL OF SELECTED GRANULAR MATERIAL CATEGORISED AS NON PLASTIC UNIFORMITY GRADED WITH A COMPACTIBILITY FACTOR NOT EXCEEDING 4.
- PIPES SHALL NOT BE Laid IN WATER AND TRENCHES SHALL BE KEPT DRY UNTIL TESTING AND BACKFILLING IS COMPLETE.
- MANHOLE COVERS SHALL BE CAST IRON TYPE 2A IN ROADSIDE AND PARKING AREAS AND TYPE 4 MEDIUM DUTY IN UNPAVED AREAS.
- COVERS AND FRAMES SHALL COMPLY WITH SANS 556-1992 SPECIFICATION AND SHALL BE BEDDED IN A CONCRETE COLLAR OF 200mm/150mm CONCRETE.

REVISIONS

REV	DESCRIPTION	DATE	BY
0	FOR CONSTRUCTION	09.02.15	COB/

CLIENT
PROVINCIAL GOVERNMENT: WESTERN CAPE

DEPARTMENT OF TRANSPORT AND PUBLIC WORKS
DEPARTMENT VAN OORDEBARE
WERKE EN VERWERK
ISBEE LEZO THUTHO
NEMSEBENZO YOLUTU

CHIEF DIRECTORATE WORKS

Consulting Engineers & Project Managers
OF FOUR BUILDINGS
SANS 1041-2001
REGISTERED

BSP Consulting Engineers PROPRIETARY LTD

CONSULTING STRUCTURAL & CIVIL ENGINEERS
CAPE TOWN & JOHANNESBURG

PROJECT
MITCHELLS PLAIN HOSPITAL

TITLE
SITE SERVICES:
STORMWATER LAYOUT
SHEET 2 OF 2

Date: 13 AUGUST 2008 Drawn: JMG
Checked by: JMG Approved by: JMG

File No:
WH-1-133-1-CE

Drawing No: 16169/WR/100/006 Rev No: 0

Appendix B

Simple Economic Model User Guide

University of Cape Town

B. Using the Simple Economic Model

B.1 Introduction

The following section has been developed to help assist the user in fully utilizing the functions of the SEM

B.1.1 Getting Started

The model opens on the front page, as shown in Figure B.1. Once Macro's have been enabled it will be possible to navigate to the appropriate sections of the model by clicking on the appropriate "Go" button. Throughout the model buttons are available to navigate between sections

Stormwater Management Simple Economic Model - Simplified -South Africa-		
Ensure MACRO's are Enabled		
Contents		
1	Single Component LCCA	GO
2	SuDS 'System' Contents Page	GO
3	Conventional System Contents Page	GO
4	Accounting for Environmental Goods & Services	GO
5	Comparative Charts	GO
6	References	GO

Figure B.23 Front Page, SEM

It is important to recognize that by and large the SEM is a calculation module, limited data is entered. Instead the accompanying Appendix F of Fact Sheets should be used to Source data as shown in Figure B.2

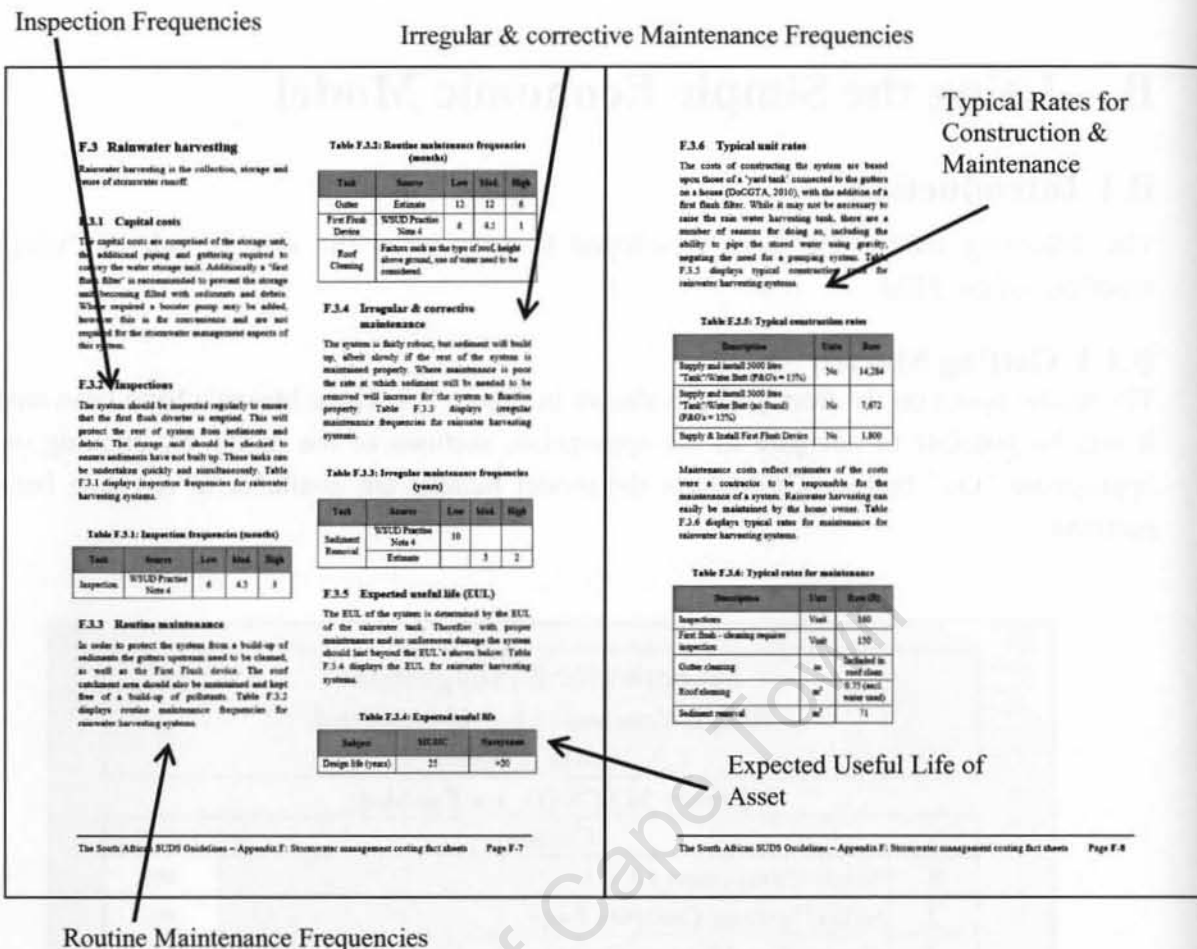


Figure B.24 Data contained in Fact Sheets

B.1.1.1 Ensuring Macro's are enabled

It is important that Macro's are enabled. The macros aid in calculation and navigation through the numerous spreadsheets. In order to enable Macros in Excel 2007 or 2010 the following eight steps must be followed:


- Step 1: Select "File"
- Step 2: Select "Options"
- Step 3: Select "Trust Center"
- Step 4: Select "Trust Center Setting"
- Step 5: Select "Macros"

Step 6: Select “Enable all Macros”

Step 7: Select “OK”

Step 8: Select “OK”

B1.1.2 ‘in program’ Help

Wherever the user is required to enter data or perform a task the heading contains an Excel ‘comment’ denoted by the following symbol: (). By selecting the heading the ‘comment’ that will be shown will explain what data is required, and where it may be accessed.

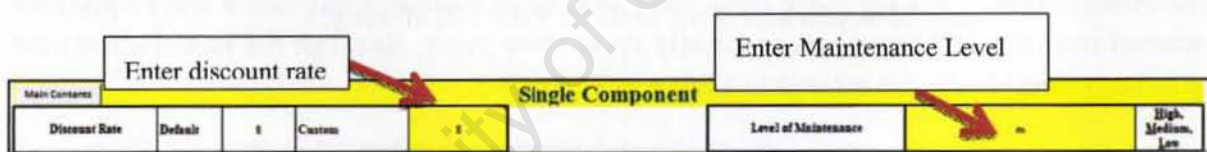
B.2 Single Component LCCA

This Spreadsheet allows a user to consider a single technology and consider the costs and benefits over a life cycle. To use this spread sheet the following steps should be followed:

Step 1: Getting Started

From the SEM front page (Figure B.1) select “Single Component LCCA”. This will take the user to the Single Component LCCA spread sheet.

Step 2: Enter Maintenance Scenario & Discount Rate for analysis



Main Contents				Single Component			Level of Maintenance		
Discount Rate	Default	8	Custom				High	Medium	Low

Figure B.25 Enter Maintenance Scenario & Discount Rate

Once all the data is entered the user may change the selections, but no calculations will be undertaken unless a Level of Maintenance is entered. If a discount rate is not entered the default setting of 8% will be used.

Step 3: Enter design and construction data

The Design & Construction data may be entered as per a standard schedule of rates and quantities. Adjustments for VAT, Contingencies etc. may be made, as shown in Figure B.4. Should the User simply have a unit cost, this may be entered. If a single value is entered for the cost of the system, it will override any entries into the schedule of rates and quantities.

2.1) Routine - Cleaning and inspection

Description of Task	Unit	Quantity	Unit Rate	High		Medium		Low	
				Recurrence (#/annum)	Unit Rate	Recurrence (#/annum)	Unit Rate	Recurrence (#/annum)	Unit Rate
Inspections & Routine Maintenance									Total Annual

2.2) Periodical - Corrective

Description of Task	Unit	Quantity	Unit Rate	High		Medium		Low	
				Recurrence (years between maintenance)	Unit Rate	Recurrence (years between maintenance)	Unit Rate	Recurrence (years between maintenance)	Unit Rate
Irregular & corrective Maintenance									

Figure B.28 Entry of maintenance data

Step 6: Enter the Asset Life Cycle & Disposal Cost

The second last step require the entering of the assets expected life span and the costs of disposal at the end of the assets life, as shown in Figure B.7

Expected Life Span (yrs.)			Quantity (# of components)	Replacement Cost per individual component	Total Replacement cost (For all)
High	Medium	Low			
50	50	50	10	400	4000

Figure B.29 Entry of asset EUL and disposal cost

Step 7: View Results & Conduct Sensitivity Analysis

It is now possible to view the results and by adjusting the level of maintenance or discount rate conduct a sensitivity analysis.

B.3 SuDS Full System

The SuDS Full System comprises 12 individual spreadsheets that analyse individual SuDS options over a user specified analysis period. The analysis includes the ability to account for EGS costs or benefits associated with the specific SuDS. The User is able to specify whether each SuDS option is a Source, Local or Regional scale. Based on the specifications the results are aggregated. Firstly, according to scale and then as a complete system where once again the user may input EGS costs or benefits that have not yet been included. Results are then available at each scale.

Step 1: Getting Started

From the SEM front page (Figure B.1) select "SuDS System Contents Page". This will take the user to the SuDS System Control Page shown in Figure B.8.

Step 2: Enter Selected SuDS Options

The User may enter up to 12 SuDS options (as per the families in the SA Guidelines) that are to be modelled as part of the system. Where a User intends using derivatives of the same type of SuDS these should not be used /done separately but will be accounted for in the spreadsheets for the 'Type'

Step 3: Enter Parameters

Once all data is entered the user may change the selections, but no calculations will be undertaken unless a level of maintenance, discount rate and analysis period is entered (As shown in Figure B.30). These settings will be used for all aspects of the SuDS system and can only be adjusted on the "SuDS System Contents Page". Each SuDS option will show the results for all three maintenance regimes. In the comparison with the conventional system only the maintenance regime selected here will be compared.

SuDS 'System' Contents Page

Main Contents

SuDS Options Index Page

		Click "GO"
1	Rainwater Harvesting	GO
2	Green Roofs	GO
3	Soakaways	GO
Enter Types of SuDS which form part of System4		
6	Buffers & Filter Strips	GO
7	Detention Ponds	GO
8	Retention Ponds	GO
9	Wetlands	GO
10	Other 1	GO
11	Other 2	GO
12	Other 3	GO

SuDS Results Index Page

		Click "GO"
1	Source Controls	GO
2	Local Controls	GO
3	Regional Controls	GO
4	SUDS SYSTEM	GO
5	'Cost' Treatment Train	GO

Settings

Level of Maintenance	M	High, Medium, Low
Discount Rate	1	%
Analysis Period	50	Years

Enter Parameters 6:00 PM

Clear All SuDS Options input data

Figure B.30 "SuDS System Contents Page"

Step 4: Select a technology

By selecting a technology and clicking "go" the appropriate analysis sheet will be opened.

Step 5: Set Scale of SuDS options

For the purposes of financial modelling the scale of the SuDS option needs to be set as shown in Figure B.31

Control Level	R	Source, Local, Regional
---------------	---	-------------------------

Figure B.31 Enter Scale of SuDS

Step 6: Enter Technology Information and Capital Data

Up to ten derivatives of the same “technology group/family” may be modelled. To avoid conflicts in maintenance schedule, each technology is assigned a “code” (1-10). When entering data for this specific derivative the appropriate code should be entered as shown in Figure B.32.

The Total Acquisition Costs must be entered as shown in Figure B.32 (i.e. if 100 rainwater tanks costing R8000 are used, a value of R800 000 should be entered).

If the User wishes to estimate maintenance costs as a % of CRC then this may be entered, but no further data with respect to maintenance should be entered. Note: the spreadsheet will change colour to indicate this is a value is entered. Use of this facility is not encouraged due to the inaccuracies with which it is associated.

1.) Capital Expenditure					
1.1) Capital		Enter Description	Enter Total Acquisition value		
Technology Code	Technology Description	total Capital Value/CRC	Total O&M as % of CRC	Total	
1	5000 liter tanks	800000		0	
2	2000 liter tanks	5000000		0	
3				0	
4				0	
5				0	
6				0	
7				0	
8				0	
9				0	
10				0	
	Value	5800000	Total O&M	0	

Not Technology Code is associated with technology description

Figure B.32 Entry of design & construction costs

Step 7: Enter ‘Establishment Costs’

The establishment costs, are costs incurred over and above routine maintenance and inspections (up to three years). These are entered as shown in Figure B.33.

4.) Life cycle data entry checks					
	Technology Descript				
	5000 liter tanks	2000 liter tanks	0	0	0
Category	1	2	3	4	5
Capital	Data Entered	Data Entered	No Data Entered	No Data Entered	No Data Entered
Establishment	Data Entered	No Data Entered	No Data Entered	No Data Entered	No Data Entered
Inspections	Data Entered	No Data Entered	No Data Entered	No Data Entered	No Data Entered
Routine Maintenance	Data Entered	No Data Entered	No Data Entered	No Data Entered	No Data Entered
Irregular & Corrective	Data Entered	No Data Entered	No Data Entered	No Data Entered	No Data Entered
Asset Life Cycle	Data Entered	Data Entered	No Data Entered	No Data Entered	No Data Entered

Figure B.35 Data entry checks

Step 11: Account for Ecosystem Goods & Services

A vital step in the process is to account for Ecosystem Goods and Services (EGS). The model allows for four possible inputs for each scenario as shown in Figure B.36. If it is possible to attribute a value for EGS to a specific SuDS option, this should be entered now. If the EGS are attributable to the system as a whole this should be entered in Step 15.

5.) Accounting for Environmental Goods & Services			
	High	Medium	Low
Annualised Benefits			
Annualised Cost (DAC)			
'Capital' Benefits			
'Capital' Costs (DAC)			
Note : only include costs and benefits specific to SuDS Option			

Figure B.36 Accounting for Environmental Goods & Services

Step 12: View Results for SUDS option

It is now possible to view the results and compare each maintenance regime, and by adjusting the discount rate, conduct a sensitivity analysis.

Step 13: Repeat procedure for other SuDS options

The above procedure may now be completed for up to 12 other SUDS options, and associated derivatives.

Step 14: View results on three scales

It is now possible to view the results. The different forms of results and adjustment of the analysis parameters may be accessed from the SuDS Contents Page (Figure B.30). A valuable representation of the results is the SuDS 'Cost' Treatment Train that presents a breakdown of the costs at each scale. This may be used to show interested parties what they may be liable for, and in what phase of the project's life cycle they could be liable. The SuDS 'Cost' Treatment Train, is shown in Figure B.15.

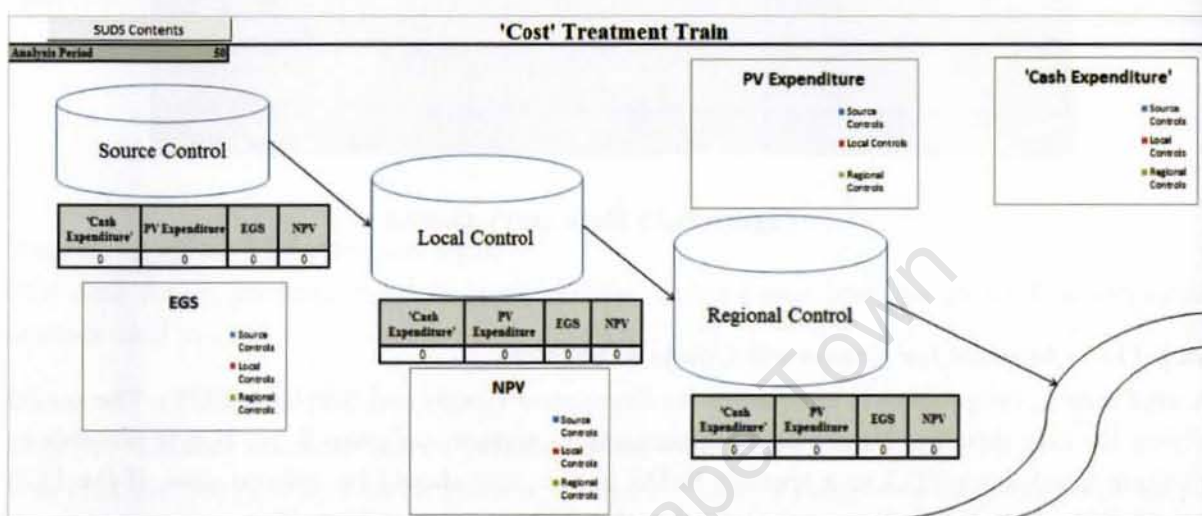


Figure B.37 SuDS 'Cost' Treatment Train

Step 15: Account for remaining EGS

Should there be EGS that have not been accounted for, or can only be estimated on a regional/system wide scale (as per DAC), this should be entered into the SuDS Full System sheet that may be accessed from the SuDS contents page.

Step 16: View System Wide Results and conduct Sensitivity Analysis

It is now possible to view the results and by adjusting the level of maintenance or the discount rate, conduct a sensitivity analysis. The different forms of results and adjustment of the analysis parameters may be accessed from the SuDS Contents Page (Figure B.30)

B.4 Conventional Full System

The Conventional Full System is considered one "technology family", essentially the same as the entry sheets for individual SuDS options.

Step 1: Getting Started

From the SEM front page (Figure B.23) select "Conventional System Contents Page". This will take the user to the Conventional System Control Page shown in Figure B.386.

Main Contents		Conventional System Contents Page		
SuDS Options Index Page		Settings		
1	Conventional System	Level of Maintenance	M	High, Medium, Low
	GO	Discount Rate	8	%
		Analysis Period	50	Years

Figure B.38 Conventional System Contents Page

Step 2: Follow Steps 3-12

The user should then follow steps 3-12 from "SuDS Full System"

B.5 Viewing results for comparative studies.

A series of results are available. These may be viewed by selecting "Comparative Charts" on the front page (Figure B.23).

B.6 Accounting for Environmental Goods & Services

The valuation of Ecosystem Goods and Services (EGS) is central to this model. While many tools are available for conducting LCCA, few are available for completing calculating the EGS supplied/consumed by a system. The valuation of EGS is the most significant feature of the SEM as it allows for SUDS and conventional stormwater management systems to be fairly compared. Using the DAC and Rainwater harvesting and reuse tools

B.6.1 Using the DAC Tool

The DAC tool provides a quick, conceptual estimate of the EGS. This tool applies the 'Substitute Cost Principle' in valuing the EGS in the form of the quantity management and quality treatment supplied by SUDS system. The assumption is then made that conventional systems externalize the equivalent value, in the form of EGS, onto the environment at large. The DAC tool is essentially concerned with estimating the EGS on a regional scale for Quantity and quality management of runoff before it impacts on the environment.

B.6.1.1 Procedure

Step 1: Getting Started

From the SEM front page (Figure B.23.1) select “SuDS System Contents Page”. This will take the user to the SuDS System Control Page shown in Figure B.39.

Damage Avoidance Cost - DAC

SuDS System Contents

Storm Type

DAC - Treatment

DAC - Land Value

Run Analysis

Final Answer

Cost for treatment: 64790 R

Cost for buying: 708 EA

Final Answer: 67:00 PM

Formula: $c = \frac{\text{Lag time}_{\text{Site}}}{\text{Area (km}^2)} \times 0.15$

Figure B.39 DAC Tool

Step 2: Enter Storm “Depths”

- Determine the water quality volume (WQv) storm depth: The WQv storm depth is the depth of rainfall, over 24 hours, requiring water quality treatment. i.e. in Cape Town it would be the depth of rainfall over 24 hours for a ½ year 24 hour storm.
- Determine the quantity control volume storm depth: The QCv storm depth is the depth of rainfall, over 24 hours requiring quantity management.

Step 3: Enter Lag time

Determine catchment lag time: Calculate the catchment lag time based on catchment characteristics. Adjust the lag time to be appropriate for the tool with the aid of the following equation:

$$\text{Lag time}_{\text{DAC tool}} = \frac{\text{Lag time}_{\text{Site}}}{\text{Area (km}^2)} \times 0.15$$

The maximum catchment size is 15 hectares. For larger catchments the catchment will need to be subdivided into areas equal to, or smaller than, 15 hectares.

Step 4: Enter discount rate

A discount rate needs to be entered. This should be the same discount rate being used for the analysis. When the user changes the analysis discount rate, the DAC should be recalculated and re-entered.

Step 5: Enter EGS parameters

Two parameters must be set by the user i.e. the reduction in peak flow as a percentage and the volume of recharge that is entered as a % of the Water Quality Volume.

Step 6: Enter Effective impervious area

The runoff is calculated by assuming 100% runoff from the area that has been entered. This area is termed the Effective Impervious Area (EIA), also referred to as the Directly Connected EIA.

Step 7: Select Storm Type

The model is able to calculate a DAC for five different storm types i.e. the four South African SCS 24 hour storms and a 24 hour storm of constant precipitation. The user must select the storm that is appropriate for their site.

Step 8: Set Land Value Parameters

Where land is freely available for such a facility the value of land take may be assumed to be zero. Where land is not freely available for such a facility the value of land take must be considered. The user must then enter the value of undeveloped land per square meter.

Step 9: Run Analysis

An analysis must be run. This will calculate the DAC according to the parameters set by the user. The user must select the "Run Analysis" button.

Step 10: Result

The total DAC is calculated and may be entered into appropriate sections of the SEM.

B.6.2 Using the rainwater harvesting and reuse tool (RWHR Tool)

The RWHR Tool simulates a storage unit's performance based on actual rain fall data as well as the mean annual precipitation. This allows a user to see what could theoretically be captured, and what will theoretically be collected. The tool works by considering the daily inflows and outflows from the system. Over a period of time this allows the user to determine how much water might be 'reused' and thus the benefits of the system.

B.6.2.1 Procedure

Step 1: Getting Started

From the SEM front page (Figure B.23) select “Accounting for Environmental Goods and Services.”

NOTE: The RWHR tool is comprised of two separate sheets, the first is for entering the rainfall data, the second is for entering the design data and running an analysis.

Step 2: Input design data

Select “Daily rainfall input”. This will take the user to the data input page, shown in Figure B.40, where the data may be entered for up to 10 years. The ‘Storm Depth’ is the total depth of rainfall for each day.

Input Rainfall Data (Daily)				
Date	Year	Month	Day	Storm Depth (mm)
January 1, 2009	2009	1	1	0
January 2, 2009	2009	1	2	0
January 3, 2009	2009	1	3	0
January 4, 2009	2009	1	4	0
January 5, 2009	2009	1	5	0
January 6, 2009	2009	1	6	0

Figure B.40 Rainfall Data Input

Step 3: Enter design data

Select “Rainwater Harvesting & Reuse”. This will take the user to the design and analysis page. All the design data should be entered as specified in the comments.

Step 4: View analysis & results

The results are presented in three manners. The first is a column chart shown in The second as table of figures as shown in . Thirdly as an animated column chart showing the analysis on a day by day basis, as discussed in Step 5.

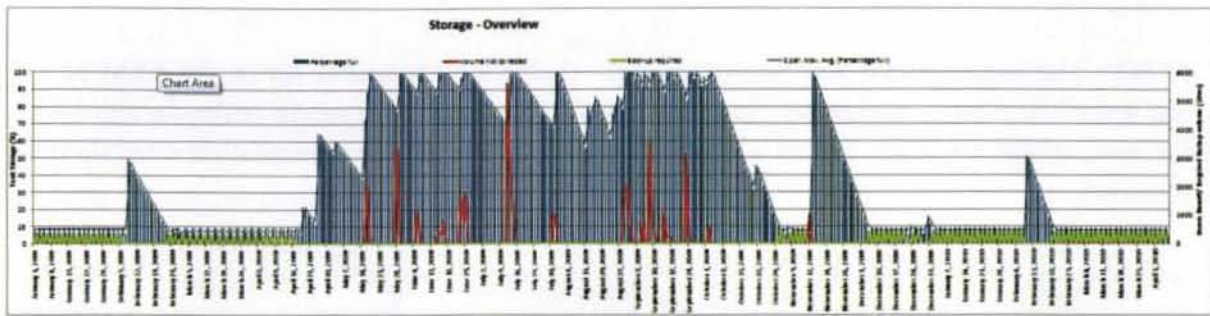


Figure B.41 Column Chart showing results of analysis

Results Summary
From Model

Total Runoff (L)	Total Volume Captured (L)	Total Volume Consumed (L)	Total Bank-up Volume (L)	% of storage available	Days Requiring Bank-Up water	Annual runoff (L)	Annual runoff (L)
8029	2985	72476	22668	62	681	6874	6874
Average Annual Runoff	Average Annual Volume Captured (L)	Average Annual Volume Consumed (L)	Average Annual Bank-up Volume (L)	Average Annual % of storage available	Average Annual Days Requiring Bank-Up water	Annual runoff (L)	Annual runoff (L)
64796	2392	98174	29571	72	263	not	2392

From Annual Collectable Runoff Calculations

Annual Collectable Runoff
77488

Figure B.42 Summary of results

Step 5: View Animation

The animated results are available as a graphic tool to allow the user to better visualize how the storage unit is utilized over time. The user must enter the Start and end dates of the analysis, as well as the speed of the analysis (1-5) as shown in Figure B.21. Once this information is entered the user must click "Run Animation" to view the animation.

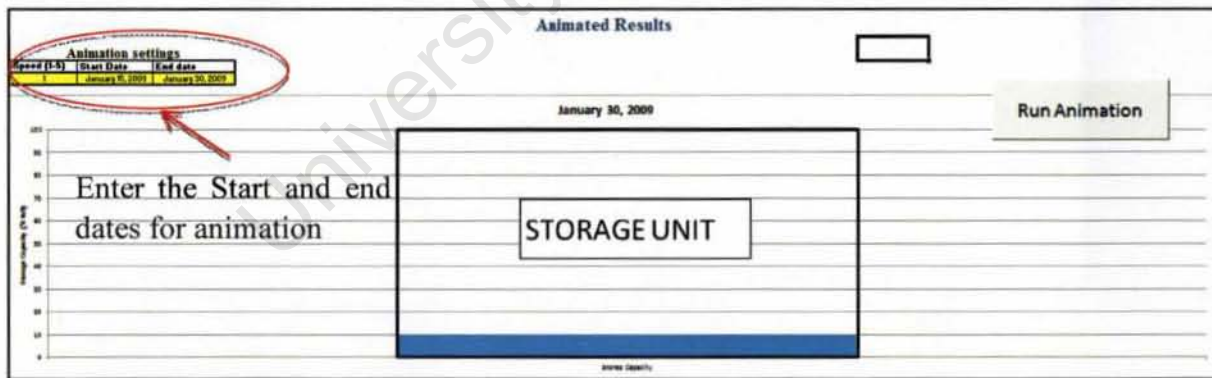


Figure B.43 Animated Results

Step 6: Calculate benefits

The final step is to calculate the value of the benefits. This has not been automated as a number of values could be considered appropriate. Based on the results, shown in Figure B.42, the user must enter: the volume of water reused, the value of the water, and the cost of electricity to pump the water should a pump be used; as shown in Figure B.44 .

NOTE: The maintenance and operation costs should be accounted for in the SEM already, and therefore these costs are not deducted here. Additionally it is worth noting in cities where the costs of sanitation are linked with water consumption, saving in sanitation rates should be included.

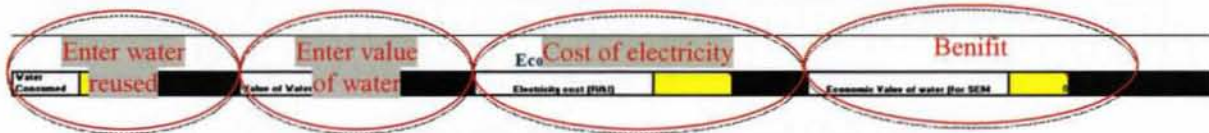


Figure B.44 Calculation of Benefits

Appendix C

Simple Economic Model (SEM) on DVD

University of Cape Town

Appendix D

Proposed South African SuDS Guidelines Appendix D: Life cycle costing of stormwater management

University of Cape Town

D.1 Introduction to document

Appendix D is intended to give a brief introduction to the important aspects of costing SUDS. Appendix E describes a costing tool that is available as part of the guidelines. Appendix F provides useful data for the tool. The document is not aimed as a detailed guide to costing, rather it is aimed and structured to specifically highlight aspects relevant to SUDS and identify relevant literature sources to aid those currently working with, designing, tendering or promoting the use of SUDS.

- Section D.2 highlights the importance of considering these during the design process;
- Sections D.3 – D.5 cover the basics of estimating the associated costs for different phases of the systems life cycle costing;
- Section D.6 discusses international comparisons of SUDS and conventional designs citing from studies from the United Kingdom, United States of America and Australia; and
- Section D.7 discusses techniques for calculating and analysing life cycle costs of stormwater systems;

D.2 Principles affecting costs

SUDS are fundamentally different to conventional systems and therefore the factors that influence their costs, both capital and operating are different. This section highlights how the principles of SUDS and design decisions impact on the costs of a SUDS system.

D.2.1 The SUDS treatment train

In the process of selecting SUDS components for new development, it is crucial that the SUDS principles be considered. Firstly SUDS, unlike conventional piped systems, are not solely a quantity management solution, quantity, quality and amenity also need to be considered. This is commonly expressed in the shape of SUDS triangle, Figure D.1, which identifies the solution as lying within the zone where all three criteria meet. It is therefore important to recognize that the

total costs for any drainage system should reflect everything required to keep the system operating from a quantity and quality and amenity perspective.

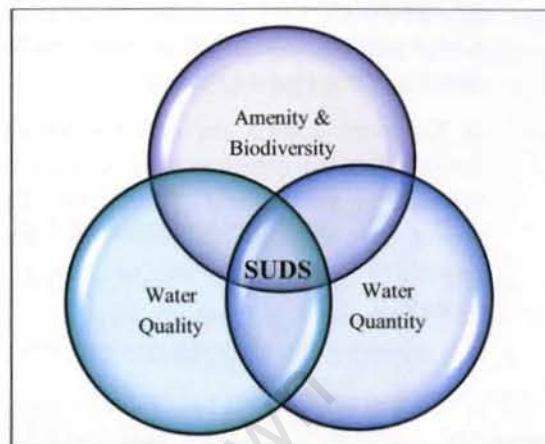


Figure D.1: SUDS triangle

Secondly, the effectiveness of a SUDS system is based on the use of a treatment train, where each successive unit process acts to further treat the runoff, as illustrated in Figure D.2 'Good housekeeping' is essential to minimize regular maintenance, especially litter collection.

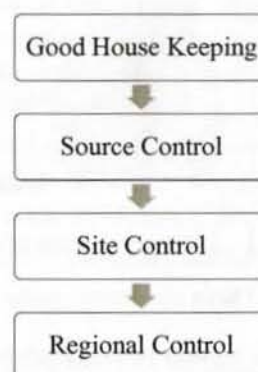


Figure D.2: SUDS Treatment Train

D.2.2 Treatment train design

The three treatment trains shown in Figure D.3, could all potentially meet the local pollutant removal criteria in the short term for a hypothetical catchment. It may therefore seem logical to use treatment train 1, to contain costs. However:

- In Treatment Train 1, all the runoff with associated pollutants is piped directly into

the wetland. This implies that all the suspended solids will collect in the wetland, which will require frequent removal

- ii) In Treatment Train 2, the swales convey the runoff to the wetland. During this process the swales will filter the runoff and remove a large portion of the sediment, lessening the quantity of entering the wetland
- iii) In Treatment Train 3, the runoff is further detained in a dry detention pond before it is released to the wetland. This allows for almost all sediment to settle out and preventing them from entering into the wetland.

D.2.3 Further reading

The SUDS Treatment Train Assessment Tool (STTAT) has been developed at the University of Abertay Scotland. The tool considers the:

- Risks of pollution to the receiving water body;
- The treatment provided in a treatment train; and
- Maintenance and 'survivability' of a SUDS option within the treatment train.

Although the tool was calibrated for sites in

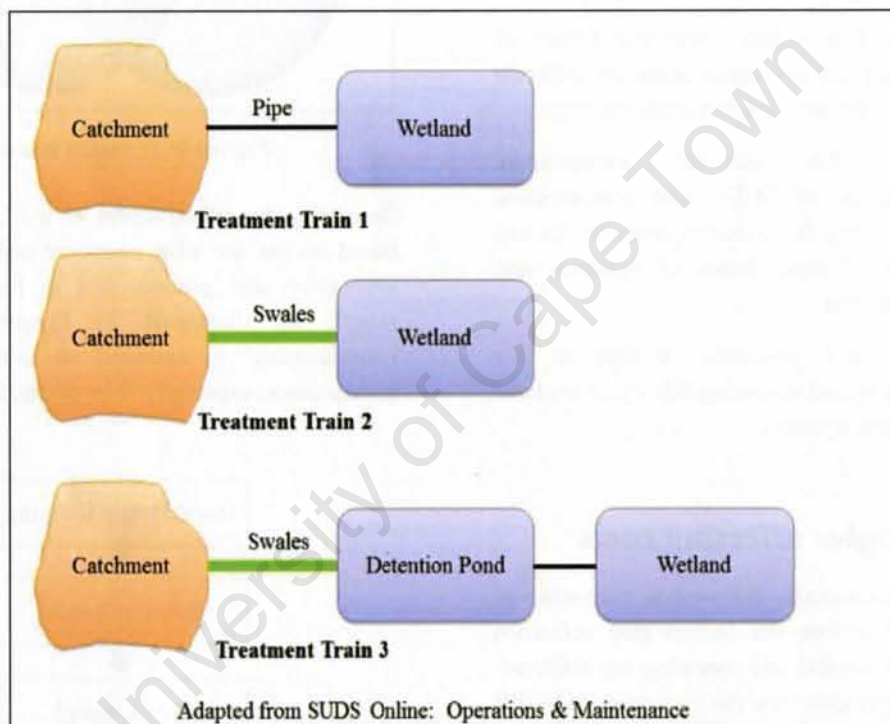


Figure D.3: Three treatment trains (adapted from SUDS Online : Operations & Maintenance, 2010)

Treatment Train 1 may have the lowest capital cost (not necessarily so), but since it is generally more cost effective to remove sediments from dry above ground SUDS (Berwick, 2011), both Treatment Trains 2 and 3 might well prove to be more cost effective in the long term. Treatment Train 3 may be over designed, although this depends on the catchment, pollutant load, and receiving water body. It is therefore vital that the long term functioning of the SUD technology and treatment train is considered as part of the design and costing process.

Scotland, it gives a good conceptual view of the efficiency of treatment trains and clearly identifies good combinations of different SUDS options. Further it demonstrates how a poor treatment train, or lack of one, reduces the potential of the system to manage pollutants long term.

D.3 Capital costs

The following section outlines the factors that need to be considered when designing and costing SUDS.

D.3.1 SUDS Costs

The majority of expenditure in SUDS is related to earthworks and landscaping. Estimating accurate unit rates is quite difficult due to the variation in the rates, especially within the landscaping profession. Additionally the following aspects of a development will impact on the costs of the system:

- Project scale and unit costs;
- Retrofits vs. green fields;
- Regulatory requirements;
- Public vs. private design and construction;
- Contractor vs. public works crew;
- Flexibility in site selection, site suitability;
- Partnerships; and
- Levels of experience with the technologies, by both designers and contractors (Lampe *et al.*, 2005).

The last point is of additional relevance in South Africa where the 'SUDS approach' is relatively new.

D.3.2 Establishment costs

An important aspect that should be in the capital costs is the cost of establishing the SUDS option. Many SUDS options make use of vegetation e.g. swales, wetlands and green roofs. These SUDS options at first require irrigation and replanting until the vegetation is fully established. These costs may be difficult to accurately determine.

D.3.3 System costs

Section D.2, explains the importance of considering a SUDS system as a treatment train, and not as individual components. Unlike a conventional system, each component (SUDS option) has a range of performance variables. Each of these variables has potential impacts on the costs of implementing the specific SUDS option, as well as on the cost of the future maintenance requirements of the system as a whole. It is therefore important that when optimizing the system a range of performance variables and their impacts on maintenance costs be considered.

D.3.4 Land take

Developers may be concerned that SUDS options may decrease the developable area (Buys & Aldous, 2009; ECONorthwest, 2007). This concern is real, as many SUDS options require a larger land take than conventional options. On the other hand, if SUDS are correctly implemented – considering quantity, quality and amenity – add value to the properties.

D.3.5 Further reading

Woods-Ballard, B, Kellagher, R, Martin, P, Jefferies, C, Bray, R & Shaffer, P, 2007, *The SUDS Manual*, CIRIA 697, London

Narayanan, A. and R. Pitt. (2005). *Costs of Urban Stormwater Control Practices*. Stormwater Management Authority of Jefferson County, AL

D.4 Operation & maintenance

D.4.1 Design for maintenance

The design process must fully consider the maintenance requirements. Facilities should be design to be as maintenance free as possible, however all competent designers should "*recognise that all structures require periodic maintenance, inspection and repair* (Debo & Reese, 2003)". Designs should therefore allow for the frequency and types of maintenance that the system will require (Berwick, 2011), and the associated cost should be considered as part of the design process.

D.4.2 Importance of on-going maintenance

It is vital that SUDS are maintained to ensure performance – quantity and quality and amenity values are maintained (Berwick, 2011; Haubner *et al.* 2001; Woods-Ballard *et al.*, 2007). "*The question is not whether stormwater management system maintenance is necessary in a community. Rather, the question is how a community's maintenance programs will be budgeted, staffed, and administered, and who has responsibility for managing inspections, scheduling periodic required maintenance, and funding remedial work.*"

(Haubner *et al.*, 2001) SUDS require constant maintenance to ensure proper functioning. Failure to do so results in premature failure. Failure will also result in the system needing to be overhauled which may have significant cost implications. In the absence of proper maintenance, the condition of conventional stormwater infrastructure will initially deteriorate slowly, whilst SUDS will deteriorate at a more rapid rate. Continued failure to maintain systems will accelerate the system's loss of condition resulting in premature failure.

Poor design and failure to maintain SUDS systems results in many SUDS failing prematurely, some within 5 years of construction, even though expert judgement suggests they should last for up to 50 years.

D.4.3 Typical maintenance tasks

All SUDS require regular inspection to ensure that potential problems are identified and dealt with timeously. SUDS also require regular/routine maintenance which includes the following tasks on an annual or more regular basis to ensure proper functioning (Woods-Ballard *et al.*, 2007; Berwick, 2011; Lampe *et al.*, 2005):

- Litter/debris removal;
- Grass & vegetation management including cutting, pruning, invasive species removal, weeding; and
- Minor sediment removal, erosion management, etc.

Less regular maintenance, irregular maintenance is required for:

- Sediment management;
- Vegetation replacement; and
- Minor overhauls.

From time to time, corrective maintenance is done in response to failures in the SUDS integrity e.g. where a swale is eroded.

D.4.4 Levels of Maintenance

Maintenance may be considered at three different levels, as detailed in Table D.1, When considering what level of maintenance is appropriate, it is important to refer back to Figure D.1 It is important to recognise that amenity is a central SUDS principle and therefore this requires maintenance as well. In certain circumstances, for example where a detention pond is out of sight and has no amenity value, the lowest level of maintenance would be appropriate (performance functioning). Conversely, upmarket gated communities may emphasise the aesthetic aspects of SUDS and hence a high level of maintenance, focusing on amenity aspects would be important. Generally, the medium level that considers all aspects of SUDS – quality, quantity and amenity – is appropriate (Berwick, 2011).

Table D.1: Levels of maintenance for SUDS (after Berwick, 2011)

Maintenance Level	Description
Low	Basic maintenance ensuring functioning of the SUD
Medium	Intermediate maintenance ensuring functionality and reasonable level of amenity
High	High maintenance ensuring both the functioning, and ensure a high amenity level (appearance). Additional maintenance is for amenity value only and does not impact on functioning

D.4.5 Life cycle costs

Unlike with conventional systems, SUDS treatment trains are fairly complex when it comes to determining both the system's life cycle and the life cycle costs. Appendix F details estimated maintenance rates and frequencies for the SUDS options. Certain costs such as the impacts of storms or heat waves on the cultivation of vegetation are difficult to predict. Extremes of either may require extensive replanting. There are also climate and site specific considerations to be addressed by the project team.

D.4.6 Further reading

Woods-Ballard, B, Kellagher, R, Martin, P, Jefferies, C, Bray, R & Shaffer, P, 2007, *The SUDS Manual*, CIRIA 697, London

Debo, T & Reese, AJ, 2003, *Municipal Stormwater Management*, Lewis Publishers, Boca Raton

D.5 Environmental goods & services (EGS)

The SUDS encourages and attempts to mimic the use of natural processes. Consequently SUDS have the potential to supply a number of environmental goods and services to stakeholders. These include but are not limited to flood mitigation, improved water quality, increased ground water recharge, improved aesthetics resulting in increasing property values. The following sections discuss the natural environmental goods and services which SUDS offers.

D.5.1 Flood mitigation

Increasing urban development is resulting in increased runoff volumes and peak flows. The cumulative effects of these impacts on flood peaks is estimated to range between 20-50% in residential areas and up to 100% in heavily industrialized areas (Drainage Manual, 2007; Brown *et al* 2008). The SUDS philosophy of onsite treatment both detains and infiltrates water on site, as well as reduces runoff velocities. This not only reduces flooding but also reduces the costs of downstream infrastructure e.g. bridges (ECONorthwest, 2007)

D.5.2 Water quality

SUDS have the ability to treat stormwater, and thus improve water quality (ECONorthwest, 2007). This is important as it is noted that stormwater is a major contributor to deteriorating water quality in cities (Buys & Aldous, 2009). SUDS improve water quality by capturing pollutants and treating them through physical, chemical, and biological processes depending on the technology implemented (Minton, 2002).

D.5.3 Ground water recharge

The use of infiltration in SUDS increases ground water recharge and supplies, a supply of water the South African government has identified as a possible resource for supplying coastal cities as the potential to build dams is decreasing (Internet On Line, 2010). Research in Atlanta, USA by Otto *et al.* (2002) suggests that impervious surfaces have reduced ground water infiltration in Atlanta by 132 billion gallons a year (500 billion litres), the equivalent water usage of 3.6 million people (ECONorthwest, 2007).

D.5.4 Aesthetics & property values

Increased urbanization has to date in general led to increased impervious surfaces e.g. pavements, sidewalks, roofs, driveways. These have the ability to increase runoff by up to a factor of 10 (Haubner *et al*, 2001; Brown *et al*, 2008). The goal of was to remove runoff from an area as quickly as possible. This ignored the aesthetics of the stormwater system. Water frontage (in upper income areas) and natural features can add to the aesthetics of an area and consequently to the value of the properties in that area. US Department of Defence (2010) concludes that "*In a variety of completed projects, micro-scale runoff management features have provided architectural interest in various forms...*" The value of the benefit is typically 5 - 30% averaging at a 10% increase in property values with a suitable view of the water bodies (Buys & Aldous, 2009). This is however not the case for all SUDS technologies; some in fact can cause depreciation in adjacent property values. Klein (2003) found that dry ponds had the opposite effect of wet ponds and that property values were 4 - 10% lower. This perspective is supported by research in Illinois, which also indicated a perceived negative effect related to their construction (Buys & Aldous, 2009). Common factors impacting on property values are highlighted in Table D.2. Certain technologies take up more land than conventional systems, and this land also has value (Buys & Aldous, 2009). There is a need to consider and to balance this aspect through the combination of technologies used.

**Table D.2: Factors affecting property values
(USEPA, 1995)**

Factors affecting property values	
Increases	Decrease
Naturally designed water bodies (Wet Ponds)	Open, unprotected water is a concern to residential owners with young children
Ponds & lakes create ideal scenery for business parks	Poor design/aesthetic appeal (dry ponds)
Positioning features near to entrances increase sales and the value of properties	Safety concerns
Property with water views or other amenities can be charged premiums	Poor maintenance leads to unsightly wet/dry ponds due to excessive algae growth or garbage build-up.
New recreational facilities (paddling, open areas etc.)	Health concerns (mosquito breeding grounds.)

D.5.5 Reduced energy consumption

"Vegetated roof covers in urban areas offer a variety of benefits, such as extending the life of roofs, reducing energy costs" (USEPA, 2000). Greenstone, 2010 showed that the use of green roofs decreases the air temperatures and insulates the roofs. This insulation effect can reduce entire building's energy requirements (ECONorthwest, 2007), while concurrently reducing pollution and improving aesthetics (US Department of Defence, 2010)

D.5.6 Value of EGS

There are a wide range of techniques available for determining the value of environmental goods and services. Table D.3 gives an overview of the common techniques. It is also possible to use multiple techniques, either to compare outcomes or to complement each other. The method or methods selected need to consider the constraints of the project in terms of data (historical & current), experience, time and personnel.

**Table D.3: Economic valuation techniques
(Pagiola et al, 2004)**

	Method	Approach	Use
Revealed preference methods	Production function (also known as 'change in productivity')	Traces impact of change in ecosystem services on produced goods	Any impact that affects produced goods
	Cost of illness, human capital	Traces impact of change in ecosystem services on morbidity and mortality	Any impact that affects health (e.g. air or water pollution)
	Substitute /replacement cost/damage avoidance cost	Uses cost of replacing the lost goods or service	Any loss of goods or services
	Travel cost (TCM)	Derives demand curve from data on actual travel costs	Valuing recreational activities
	Hedonic pricing	Extracts effect of environmental factors on price of goods that include those factors	Air quality, scenic beauty, cultural benefits
	Stated preference methods	Contingent valuation (CV)	Asks respondents directly re willingness to pay for a specified service
Choice modelling		Asks respondents to choose their preferred option from a set of alternatives with particular attributes	Any Service
Other	Benefits transfer	Uses results obtained in one context in a different context	Any for which suitable comparison studies are available

D.6 International case studies

A number of studies have been undertaken around the world, in order to determine the financial and economic implications of implementing SUDS type technologies. Different regions define SUDS, LID's, BMP's, BIOCEDs etc. slightly differently, but in general, the results are comparable. Table D.4 summarises the conclusions from a selection of international studies. Overall it appears that SUDS are usually, but not always, more economical than conventional systems. In the extreme, conventional systems can cost twice that of SUDS over the lifetime of the project. It is however important to identify 'who pays for what'. SUDS require ongoing, regular maintenance. A relatively higher proportion of the costs might be contained within this particular item.

D.6.3 Further reading

The Eco North West (2007) report supplies a very good overview of a wide range of studies into the economics of Low Impact Development (equivalent to SUDS) in the USA:

ECONorthwest. (2007). *The Economics of Low Impact Development - A Literature review*. ECONorthwest

Table D.4 Studies comparing SUDS and Conventional systems

Study	Country	Year	Report's Economic Conclusions
Lloyd <i>et al</i>	AUS	2002	"Analysis of the capital costs of the bio-filtration systems showed only a 0.5% increase to the developer. This small increase in cost was offset by the increased marketability of the estate to the consumer. The success of the project has been widely acknowledged and the Lynbrook Estate demonstration project has helped to encourage the adoption of WSUD principles and practice by others elsewhere in Australia."
Boubli <i>et al</i>	AUS	2003	"Based on the above discussion it appears that a WSUD can be delivered on most projects without imposing a cost burden. In fact a balanced WSUD may be cost neutral on smaller projects but is likely to deliver increasing savings on larger projects. "
Lloyd S.D	AUS	2004	"Bio-filtration systems provide a 25% saving to the community compared to treating runoff conventionally at a downstream constructed wetland. Additionally research found 85% of homebuyers supported the introduction of this technology in their neighbourhoods"
Sidek <i>et al</i>	Malaysia	2004	The finding of the study was that MSMA (environmentally friendly drainage) was 5% less than that of conventional systems
Coombes <i>et al</i>	UK	2004	"The benefits of WSUD source control approaches arise from reduced mains water use and reduced stormwater infrastructure... In addition, the case study demonstrates that use of WSUD source controls including rainwater tanks in new urban development's offers the economically most efficient infrastructure solution providing benefits to the community of up to \$6B in the Lower Hunter Region and up to \$5B in the Central Coast Region."
Narayanan	USA	2006	In a comparison of conventional systems and grass swales system, grass swales appeared to cost approximately a fifth of the cost over the life cycle.
USEPA	USA	2007	"The 17 case studies presented in this report show that LID practices can reduce project costs and improve environmental performance. In most cases, the case studies indicate that the use of LID practices can be both fiscally and environmentally beneficial to communities. "
ECO NW	USA	2007	A review of the economics of LID's in the USA. It generally found, with notable exceptions that LID's were more economical.

D.7 Life cycle costing

D.7.1 Introduction

When considering the costs of a drainage system, whether it is a SUDS or conventional system, it is important to understand what type of analysis is being undertaken. This section outlines the basic approaches commonly used in internationally to evaluate the costs – both financial and economic – of stormwater drainage systems. Three techniques are commonly used in evaluating the financial and economic aspects of SUDS and conventional drainage systems:

- Analysis of the capital/construction costs (CCA);
- A comprehensive Benefit Cost Analysis (BCA); and
- Analysis of the whole Life Cycle Costs (LCCA).

Each of these techniques has different advantages and short comings. Table D.5 outlines the differences between each approach. CCA is the simplest to calculate where there is limited life cycle costing data. On the other hand the result would be of relative insignificance to the majority of stakeholders except potential developers who would be primarily concerned with capital expenditure. Section D.1 emphasised the need to consider the whole life cycle of the SUDS system. It is therefore vital that the interests of all stakeholders be considered as part of the design process, especially when considering the economic arguments. Should the system's owners, either city councils or private land owners, not be able to maintain and operate the system, the system will potentially fail. Therefore a simple CCA analysis would be inappropriate.

The BCA is the most comprehensive approach, however it is difficult to undertake. The more complicated the authorisation process and detailed the studies required, the lower the potential that SUDS will appear as a viable option – especially during economically unfavourable times. The LCCA analysis, on the other hand, is commonly used internationally and would be generally the most appropriate in South Africa. By considering all expenditure over the system's life

cycle it ensures all stakeholders have a conceptual understanding of their total commitments. It is however important to recognise that there are a number of non-financial benefits to SUDS. These may be accounted for in a simplified economic life cycle cost analysis (Appendix E).

Table D.5: Techniques for analysing drainage economics

Techniques for analysing urban drainage economics	
Advantages	Disadvantages
Capital Cost Analysis (CCA)	
One of the most common studies	Considers only capital costs
Requires the minimum inputs	Ignores benefits
Can be easily completed	Goods & Services
	Does not take account of effectiveness of system
	Different stakeholder will want different information
Benefit Cost Analysis (BCA)	
Comprehensive analysis	"Requires more data and time, and costs more to produce"
Considers all economic benefits and costs	
Life Cycle Costing (LCCA)	
Considers whole life cycle costs from design to decommissioning	Still excludes economic benefits of the construction
Intermediate assessment	Can be done on a case study basis. In SA rather unlikely as the systems are not that old as to collect sufficient information

D.7.2 Life cycle costing

Life Cycle Costing is "the systematic consideration of all relevant costs and revenues associated with the acquisition and ownership of an asset". (Clift & Bourke, 1999). Life cycle costing essentially considers all the costs associated with an asset. In terms of SUDS, this would include: design, construction, establishment of vegetation (SUD dependent), maintenance (inspections, regular, irregular, and corrective), and disposal. These costs

(and any benefits) are all discounted to their present value. There are two possible Whole Life Cycle Costing analyses that may be undertaken viz. an economic or a financial analysis, as indicated in Figure D.4. The environmental costs and benefits may be economically appraised and included in the analysis. Methods for appraising environmental goods and services are discussed in Section D.5.

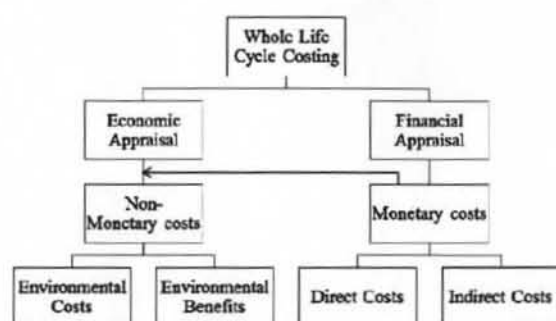


Figure D.4: Economic and financial appraisals (Lampe *et al*, 2005)

D.7.2 Formulae

Table D.4, gives an overview of the calculations undertaken to calculate the present value of expenditure. To bring future expenditure to present value the expenditure is multiplied by the relevant discount factor, Equation 1.

$$DF = \frac{1}{(1+i)^n}$$

Where:

- DF = Discount Factor
 i = Interest rate
 n = Period/year from present

The total life cycle costs is the sum of all future costs reduced to present value, as expressed in Equations 2.

$$PV = DF_0(EX_0) + DF_1(EX_1) + \dots + DF_x(EX_x)$$

Where:

- PV = Present Value
 DF = Discount Factor
 EX = Expenditure
 i = Interest rate
 n = Period/year from present

Table D.7.2 Present value calculations

Year	Discount Factor	Expenditure (regular+irregular maintenance)	PV of Expenditure	Cumulative Expenditure	
				'Cash' Expenditure	PV
0	1.00	100	100	100	100
1	0.94	100	94	200	194
2	0.89	100	89	300	284
3	0.85	200	170	500	454
... 25	0.26	100	26	3400	3500

Benefits may be calculated in the same manner and subtracted from the present value costs. This would be considered the 'net present value'.

D.7.3 Further reading

- Drainage Manual. (2007). Pretoria, South Africa: The South African National Roads Agency.
- DoCGTA. (2010). *An Industry Guide to service levels and unit costs* Department of Cooperative Governance and Traditional Affairs

Appendix E

Proposed South African SuDS Guidelines Appendix E: Overview of the
'Simple Economic Model'

University of Cape Town

E.1 Introduction

It is important that the design process, and selection of alternative stormwater strategies is done in a fair manner. Appendix E lays out the procedure to undertake such an analysis using a 'simplified economic model' (SEM) for SUDS selection, an Excel-based Simple Economic Model (SEM) was developed with four aims:

- i) Establish the life cycle costs of alternative drainage designs.
- ii) Account for the differences in environmental impacts on an 'equivalent and fair basis'.
- iii) Provide a simple method that may be applied to different sites within South Africa.
- iv) Present results in a manner that is accessible and understandable to the stakeholders.

A set of step by step instructions for using the SEM are found in Appendix G.

E.2 Overview of the SEM

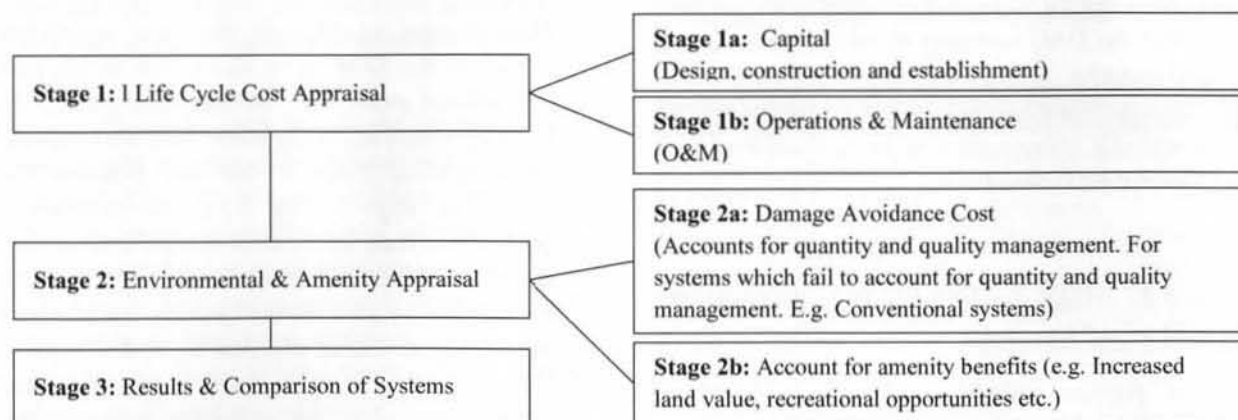
The SEM is a macro-enabled Excel workbook that can consider up to 12 groups of SuDS. For each technology the SEM considers: the total capital cost per technology/component including establishment costs for up to the first three years; the inspection costs; routine maintenance costs; irregular and corrective maintenance costs. It is possible to enter data for three different maintenance scenarios either from a maintenance

plan or making use of Appendix F to estimate the frequency of different tasks where there is a lack of local data. Additionally – and critically – the value of Environmental Goods and Services (EGS) are accounted for through the use of a 'Damage Avoidance Cost (DAC)' in the case of conventional systems. The DAC is an estimate of the minimum cost of treating the stormwater discharge to the receiving waters to a level equivalent to that provided by SUDS through the device of a virtual stormwater treatment works (the treatment works does not exist, it is merely a means to estimate the value of EGS expected from the receiving waters). The SEM can analyse stormwater management systems over any period up to a maximum of 100 years, although shorter analysis periods are generally more appropriate. The program ensures that the maintenance schedule is 'reset' when a technology/component is replaced. With the aid of this SEM it is possible to quickly and fairly complete a comparative analysis of two very different drainage systems. The output of the SEM is a number of user-friendly comparative charts and tables.

E.3 Computational stages in the SEM

The model has three distinct computational stages as indicated in Figure 1. The model may be applied in a number of ways: to compare a SUDS and a conventional design; to compare two SUDS designs (in which case Step 2a may be skipped) or to consider the costs and benefits of a single SUDS design (in which case Step 2b may also be skipped resulting in a standard LCCA).

Figure 1. Computational stages in the SEM



E.3.1 Stage 1 – Life Cycle Cost

Appraisal:

A design for the site is developed. All costs over a common life cycle are reduced to their present value. The life cycle analysis considers different maintenance regimes, i.e. High, Medium and Low maintenance for both SUDS and conventional designs, as different maintenance regimes may result in different outcomes. It is possible to enter data for three different maintenance scenarios either from a maintenance plan or making use of Appendix F to estimate the frequency of different tasks where there is a lack of local data. It is also important to recognize that different drainage systems cannot be compared at component level as, for example, a green roof cannot be directly compared with a conduit which would convey an equivalent roofs runoff to the municipal storm sewer, as the value of the municipal storm sewer would also need to be considered. Proposals need to be considered as whole systems and not individual components.

E3.2 Stage 2 – Environmental & Amenity Appraisal:

Stage 1 provides LCCAs of the monetary aspects. Stage 2 considers the non-monetary aspects. For comparison with conventional systems the EGS supplied by SUDS, but not conventional systems, need to be considered. The EGS are valued using the DAC tool described below. The DAC tool calculates an annual environmental cost to substitute for the fact that the environment is continuously treating and managing runoff from conventional systems. The SEM then reduces the costs to their present value. One shortcoming is that SUDS cater for water quality, quantity and amenity whilst the DAC tool only considers water quality and quantity. Where local data is available for the valuation of the amenity this can be entered into the model. All systems are now being considered on a 'fair and equivalent basis'.

E.3.3 Stage 3 – Results & Comparison of Systems:

The process outlined in Figure 1 should be completed for each proposed design, ensuring that

all designs are developed to manage the same design storm. The SEM aims to compare the systems in a transparent manner and thus the different cost elements are presented separately as indicated in Table 1. This also allows for a comparison of the two systems from a number of different perspectives, i.e. the capital costs – which are of particular interest for developers, the environmental costs – which are of particular interest for environmentalists, and the maintenance costs – which are of particular interest for the property owners. Sensitivity analyses may also be undertaken, for example by varying the discount rate and/or level of maintenance.

Table 1. Comparing a SUDS system with a conventional system

Stage	Item	Proposal 1 (e.g. SUDS)	Proposal 2 (e.g. Conventional)
1	a	Capital Costs	R XXXX
	b	O&M (PV)	R XXXX
		Sub Total 1	R XXXX
2	A	Quantity & Quality management (Damage Avoidance Cost) (PV)	R 0,00 (meets set criteria therefore no externalized environmental costs)
	B	Amenity (local /site specific data) (PV)	R XXXX
3		Total "Cost" (PV)	R XXXX

E.4 The Damage Avoidance Cost (DAC) tool

The valuation of EGS is the most significant feature of the SEM as it allows for SUDS and conventional stormwater management systems to be fairly compared. While many tools are available for completing Stage 1, few are available for completing Stage 2. The DAC tool provides a quick, conceptual estimate of the EGS. This tool applies the 'Substitute Cost Principle' in valuing the EGS in the form of the quantity management and quality treatment supplied by SUDS system. The assumption is then made that conventional systems externalize the equivalent value, in the

form of EGS, onto the environment at large. The value of the goods and services supplied by SUDS is calculated by considering the cost of acquiring and managing a virtual treatment facility that would produce equivalent water quality treatment

and quantity management. Typical treatment objectives considered achievable by the City of Cape Town (2009) for SUDS are presented in Table 2.

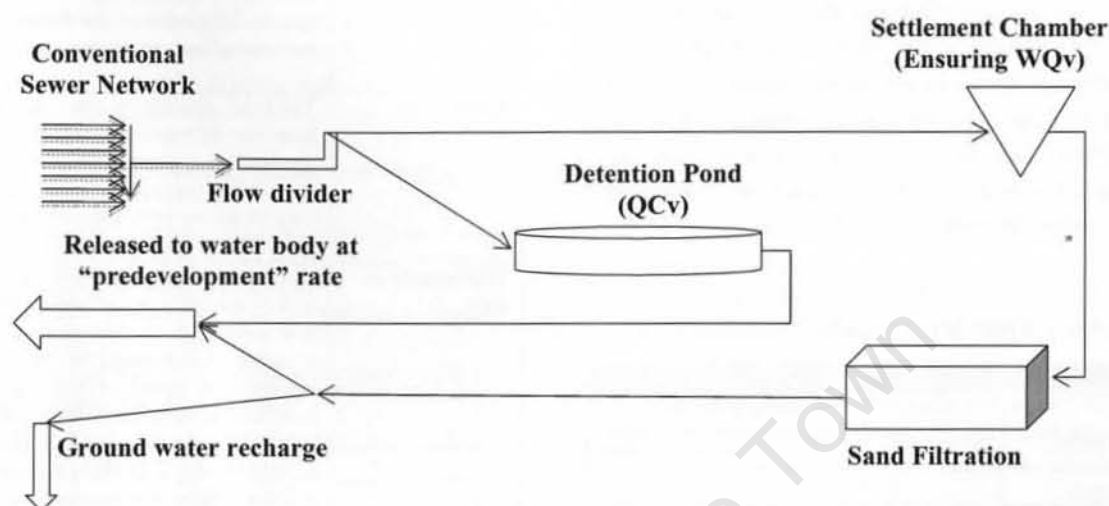


Figure 2. Schematic treatment train for virtual treatment works used to estimate the DAC

Figure 2 presents a schematic treatment train for the virtual treatment works assumed by the SEM to be the most cost-effective way of treating stormwater discharge from a conventional drainage system in order to meet the objectives described in Table 2. The water released to the receiving waters from such a facility is of a similar quality to that expected from a SUDS system designed to meet the same objectives, hence the hypothetical cost of treating conventional cost in this way may be termed the 'Damage Avoidance Cost (DAC)'. Note that the virtual facility also allows for groundwater recharge, an important additional service offered by SUDS.

The DAC needs to account for both water quality and quantity (total volume and flow rate). In South Africa the climatic conditions vary greatly from region to region. The model accounts for this by allowing the user to choose between one of five standard 24-hour design storms as appropriate for the sizing of the virtual treatment works. These include the four South African SCS storms (Southern African adaptations of the United States

Soil Conservation Service design storms as described in Schmidt & Schulze (1987)), and a 24 hour constant precipitation storm. For the same storm volume, higher intensity storms require larger and more costly treatment facilities than lower intensity storms therefore the constant precipitation design storm is the least costly and the SA SCS Type 4 the most costly. Other parameters that may be varied include: the depth of runoff; the lag time and the discount rate.

Table 2. Treatment objectives considered achievable using SUDS (City of Cape Town, 2009)

Objectives	Pollutant	Modelling Parameters
Quantity Control	Increased Peak Flows	Management of the Quantity Control volume (QCv) storm
Quality of run-off	Litter/Rubbish	100% Removal for Water Quality Volume (WQv)
	SS	80% reduction for WQv
	TP	45% reduction for WQv

In the computation of the DAC by the SEM, care was taken at all times to ensure the 'least cost principle' was adhered to. Over-estimation of the value of EGS is a criticism frequently levelled at the Substitute Cost Method. Optimal performance of each unit process was thus assumed. For simplicity sake, the model does assume a number of parameters that influence the valuation of EGS. These are presented in Table 3. The three criteria that should be met to ensure the appropriate use of the Substitute Cost Method according to Pagiola et al (2004) are listed in Table 4 alongside the justification as to how the approach adopted in the DAC meets each one.

Table 3. Fixed input parameters in the DAC

Component	Parameter	Value
Flow Diversion	Capacity	Equals peak WQv Runoff
Sedimentation Chamber	Area	20% of WQv
	Depth	2m (max)
Filtration Chamber	K (m/s)	0.6m/day
	Depth of Filter	0.5m
	Head over Filter	2m
Detention Basin	Area	Sufficient to ensure detention of QCv
	Depth	Max depth = 2m; Average Depth = 1m
	Outlet	Orifice
Effective Impervious Area	15 ha	Sets optimum size of sand filter

The calculation procedure for the DAC follows the process outlined in Figure 3. The initial parameters for the analysis are entered by the user in Step 1. The model then automatically completes Steps 2 – 6. The order of the model's calculation procedure is significant as it ensures that the facility's use is optimized i.e. the treatment facility is fully utilized before the detention facility is required, ensuring it is a 'least cost alternative'. The hydrographs for the Water Quality volume (WQv) and Quantity Control volume (QCv) storms are modelled. The treatment facility is sized to ensure that it has sufficient capacity based on the WQv Storm. The QCv Storm is routed through the facility and excess runoff that the quality treatment facility cannot manage is routed through a quantity control pond which

releases runoff at a reduced rate (30% of post development).

Table 4. DAC Justification

Criteria	Justification
Equivalent Service:	The facility ensures equal treatment to a SUDS system as per Error! Reference source not found..
Least Cost:	The DAC attempts to calculate the least cost of treating runoff from conventional systems using the most appropriate treatment works – in this case an online sand filter connected to an off line detention pond.
Willingness to Pay:	The "polluter pays" principle is widely accepted in law and therefore it is appropriate that the cost of treatment is accounted for. In conventional systems these costs are externalised onto the environment resulting in the potential loss of natural capital. It is likely that there will be resistance to service charges being levied for stormwater treatment measures but this is not an excuse for not doing so.

Step 7 involves the separate calculation of the costs for treatment and the 'land-take'. The land-take accounts for the fact that real treatment facilities would have to be located somewhere in the city and land will have to be acquired at some cost. The SEM allows for this cost to be included if so desired.

The user calculates the final DAC in Step 8. The final DAC includes an amount for treatment and an amount for land-take (if desired). The virtual facility initially assumes a catchment with an effective impervious area (EIA) equal to 15ha – an estimate of the area that will require a sand filter of roughly optimal size. This is to ensure that the cost of developing and operating the facility is based on the 'least cost principle'. The costs (treatment and land-take) associated with EIAs larger or smaller than 15ha are then determined pro-rata.

The final DAC is then exported to the main SEM spreadsheet in Step 9.

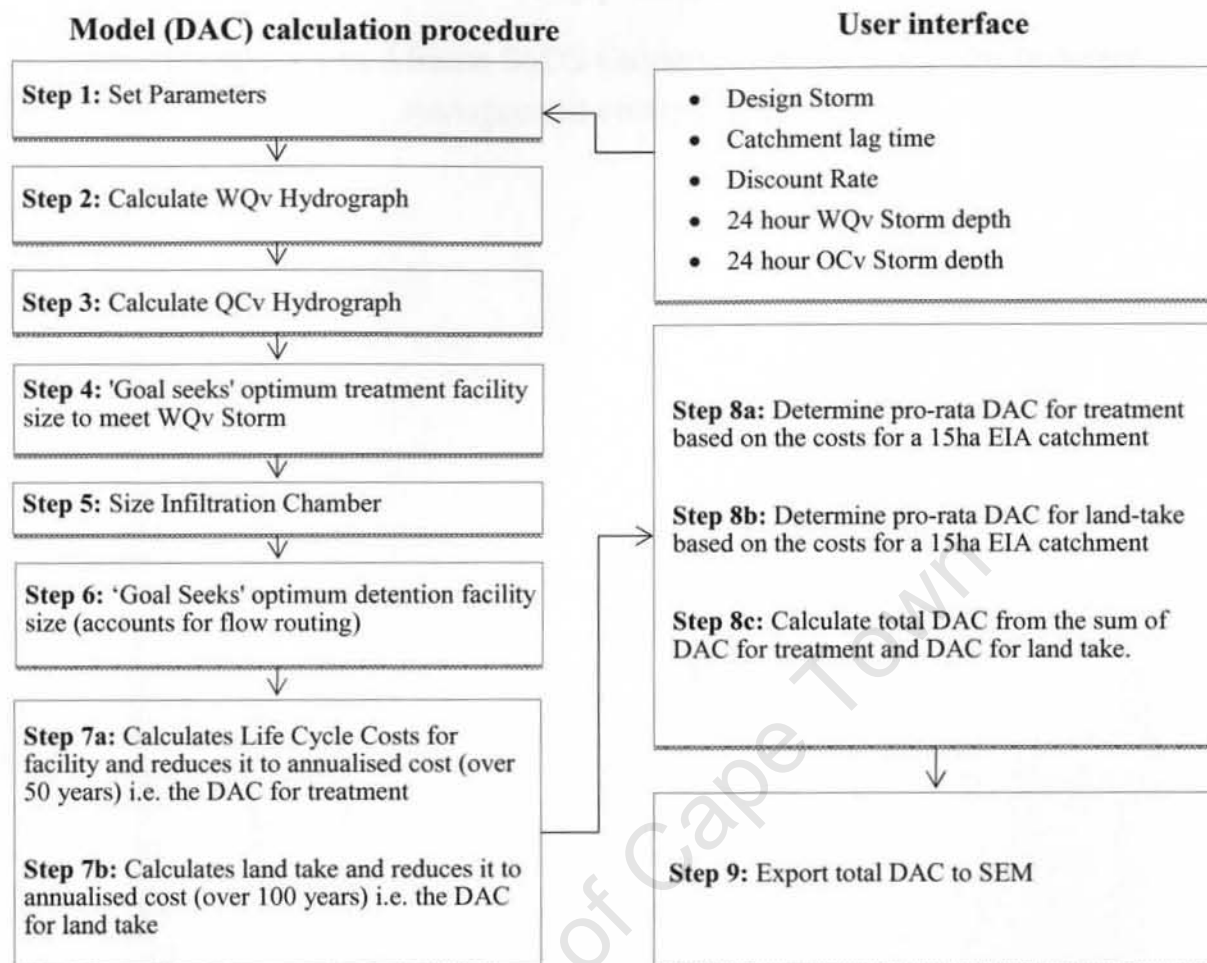


Figure 3. DAC tool calculation procedure

E.5 Conclusion

It is becoming increasingly important to be able to compare different stormwater designs on an 'equivalent and a fair basis'. LCCA's have failed to fairly consider alternative designs, through failing to account for the EGS supplied by SUDS systems. While the SEM presented above does not consider all aspects, it considers those most relevant to ensuring that the costs and benefits of different stormwater management systems may be compared in a fair manner and in a way which may be understood by a wide variety of stakeholders.

The failure to consider the impact of externalizing stormwater pollution from conventional systems is a common criticism of

most commonly used economic tools as this unfairly distorts the benefit to cost ratio away from SUDS. The SEM accounts for this through the use of a Damage Avoidance Cost (DAC) based on the Substitute Cost Principle.

The SEM offers a relatively simple method that accounts for the life cycle costs of conventional and SUDS systems while also considering impacts on the environment including: ground water recharge, stormwater quantity (flow and volume) management and stormwater quality management. The spreadsheets which make up this model ensure it is accessible to a wide range of stakeholders further simplifying the method and removing one barrier to the wider application of SUDS within South Africa.

Appendix F

Proposed South African SuDS Guidelines Appendix F: Stormwater
management costing fact sheets

University of Cape Town

F.1 Overview of fact sheets

Each fact sheet included herein contains a summary of the information required to conduct a preliminary 'life cycle costing' analysis for a SUDS design. Each fact sheet contains the following information:

- Overview of the SUDS option;
- Summary of capital costs;
- Summary of routine maintenance frequencies and costs;
- Summary of corrective maintenance predicted frequencies and costs;
- Predicted life cycle duration; and
- Conceptual value of environmental goods and services.

The information contained in each of these sections is detailed below. Although the focus of this document is not conventional stormwater drainage systems, components of conventional systems are often used as part of a SUDS system. Additionally it is worth comparing the costs of each system. Therefore a section detailing the cost relating to conventional systems has been included. Table F.1 lists the available fact sheets corresponding to the twelve primary SUDS options included in the main text of the guidelines.

Table F.1: Fact sheets SUDS options

Fact sheets	SUDS assessed
Conventional design	Inlets, outlets etc.
Rainwater harvesting	Rainwater harvesting
Infiltration Trenches / Soakaways	Infiltration trenches / soakaways
	Filter trenches
Green roofs	Green roofs
Bio-retention	Bio-retention
Grass swale	Swales (dry, wet, enhan.)
Permeable pavements	Permeable pavements
Buffer & filter strips	Buffer strips
	Filter strip
Dry stormwater ponds	Detention ponds (dry, enhan.)
Wetlands & wet Ponds	Wetlands
	Wet ponds

F.1.1 Summary of capital costs

The 'capital costs' section in the fact sheets details any problems that have been experienced in implementing specific SUDS options and the impact on their capital costs. Typical unit rates for construction are also presented.

F.1.2 Summary of maintenance costs

The inspections, routine maintenance and corrective maintenance frequencies that have been presented in this section in the fact sheets, and are largely based on work done by Lampe *et al* (2005). The results are presented for the USA and UK separately, and based on the USA format. It is worth noting that this study is available on the WERF website along with a set of MS Excel based costing tools that makes use of data from the USA. These frequencies reflect typical frequencies for individual SUDS. In reality frequencies and associated costs will be dependent on a number of factors including: land use, climate, treatment train, component design etc. In addition, typical 'routine and corrective maintenance costs. These have been sourced from builders pricing guides, discussions with members of industry, the City of Cape Town

and a range of recent tenders from across South Africa.

F.1.3 Predicted life cycle costs

Lampe *et al* (2005) failed to identify potential life cycles for individual SUDS, rather leaving this to the individual to assess. Due to the relative inexperience in South Africa, this section in the fact sheets presents a number of Life cycles as sourced from international literature. These should be applied after considerations of the local conditions verse those found in the country of origin. Explanations of possible maintenance activities for each SUDS option is included in the main body of the guidelines.

F.1.4 Typical rates

The typical rates for capital costs presented in the fact sheets are estimates that are largely based on DoCGTA (2010), and checked against recent tenders, and industry pricing manuals (Merkels & Buildaid). The 'Gauteng prices' used can be adjusted in line with the MIG Guidelines for other provinces, although adjustments will be within the range of uncertainty, and thus for a conceptual understanding of the costs, may be unnecessary. With landscaping costs, identifying typical unit rates is difficult as it is dependent on the contractors and how they determine their rates. Additionally the cost of vegetation varies significantly. Grass is a prime example. Buffalo sometimes costs more than R50 per square meter in 2010, whereas Kikuyu was typically less than half that at R20 a square meter. For swales and buffer strips this could have major cost implications as grassing is a significant cost factor. It was decided that the MIG guidelines should guide the typical rates, as this was based on an extensive research and stakeholder input. All rates exclude VAT, P&G's, and consulting/design fees. The typical rates presented for operations and maintenance have been collected from the municipality and firms within the city of Cape Town.

F.1.5 Acknowledgements

Data presented in this document has been determined by the author and none of the contributors hold any liability for errors. The author

wishes to thank the following organisations that have provided valuable assistance in developing conceptual estimates of the costs of Stormwater management; The City of Cape Town CSRM department, Department of Co-operative Governance and Traditional Affairs, Jeffares & Green Consulting Engineers, Green Card Landscaping, Water Rhapsody, Murray & Roberts, Iliso Consulting Engineers, RL Consulting, and Graeme McGill Consulting.

F.2 Conventional drainage system fact sheet

F.2.1 Municipal Infrastructure Grant (MIG) Manual

F.2.1.1 Capital costs

The MIG Manual 2010 provides estimates of capital construction costs for a range of infrastructural development, including a number of stormwater components, Table F.2.1. The estimates are built up from typical unit rates. The estimates are deficient in that there are no estimates for pipes smaller than 600 mm diameter. The manual does however supply a detailed breakdown of the typical rates on which the cost estimates were based. This is a very useful database for estimations of typical unit rates and can be used to build up estimates for varying diameters.

Table F.2.1: Capital costs for conventional drainage design – Aug 2009 (DoCGTA, 2010)

Asset	Unit	Average cost R's (Gauteng)
Unlined	m	234
Lined	m	776
Pipe culverts (600 mm diameter; Class 100D)	m	3,643
Box culverts (1500 mm x 1500 mm)	m	17,183
Low level stream crossings	m	58,379
Dewatering (subsoil)	m	5,115
Gabions	m ³	1,339
Reno Mattresses	m ³	1,582

F.2.1.2 Maintenance

The DPLG presented a set of operating and maintenance estimates as a percentage of the Current Replacement Cost of the infrastructure, as shown in Table F.2.2. These do not however seem to be particularly good estimates when compared to the costs of the tasks required to maintain such systems. Additionally no information or reference is given for the origin of these estimates. Hence while simple to use, there is the potential that these

estimates underestimate the costs of maintaining a conventional system.

F.2.3.1 Application of MIG estimates

The data and the detail that it is supplied in the 2010 MIG manual allows for this data to be used for determining estimates of capital costs. The estimates supplied in the 2006 Guidelines for Infrastructure Management should not, if at all possible, be used to estimate the life cycle costs of a conventional system as they are prone to underestimate these costs. Instead estimates should be made by calculating the costs for cleaning, minor repairs and inspections. Where data is not available, and using the MIG estimates for operating and maintenance costs cannot be avoided, the uncertainty in these values should be clearly noted. It is also important to consider the externalisation of the costs of managing stormwater onto the environment.

Table F.2.2: Operating & Maintenance Costs (DPLG, 2006)

Asset	Operat. (%CRC)	Maint. (%CRC)
Open Channels -Lined	0	1.4
Open Channels - Unlined	0	10
Pipes (<600 mm Diameter)	0	0.65
Pipes (>600 mm Diameter)	0	0.35
Nodes and Transitions	0	1
Erosion Protections	0	1.25
Hydrological Monitoring and measurement Equipment	0	1.5
Ponds	0	0.35
Pump station Mechanical plant	2	4.6
Pump station Electrical plant	3	2.3
Pump station Civil plant	0.1	0.5

F.2.2 Capital costs

F.2.2.1 Algorithm estimates

Bester *et al.* (2010) presents a set of simple to apply algorithms including all components involved in the construction of the pipe line. The

cost of manholes, for example, is averaged over the length of the pipe line. The study effectively averaged the values of many successful tenders (Bester, 2010). These are relatively useful formulae and will give an indication of an average cost for constructing a gravity sewer system. They do not account for local factors and this should be noted when they are applied. Additionally, these formulae do not consider aspects such as kerbs, catch pits and connections into the trunk line. These are important aspects that should be accounted for in any design.

F.2.2.2 Bottom-up estimates

The alternative to making use of algorithms such as those above is to build up the costs considering all the individual aspects. Narayanan & Pitt (2005), presented a simple model for this purpose. Alternatively a Quantity Surveyor should be consulted.

F.2.3 Operations & maintenance

F.2.3.1 Inspections

Conventional stormwater systems require inspections to ensure that they are being optimally managed and to identify potential failures before they occur. Table F.2.3 contains inspection estimates for conventional designs.

Table F.2.3: Inspection frequencies conventional components

Asset	Months between Inspections
Catch pits	6 - 12
Conduits	120-1,200
Lined channels	12
Unlined channels	6 - 12
Maintained watercourses	12
Intakes / headwalls	6 - 12
Vleis and wetlands	12
Ponds	12

F.2.3.2 Routine maintenance

Routine Maintenance comprises the cleaning of the infrastructure, and where necessary, the management of vegetation and the removal of sediment. The frequencies, in Table F.2.4, supplied are guides and are dependent on a number of factors including the pollution potential of the catchment. Note: the different levels of maintenance in a conventional system relate only to hydraulic functioning and public health concerns. They do not consider amenity aspects.

Table F.2.4: Routine maintenance frequencies (After CSRM, (2005))

Asset description	Months between maintenance		
	High	Avrg.	Low
Connections	6	9	12
Catch pits	6	8	12
≤300 diameter (mm)	3	16	24
375 diameter (mm)	12	22	24
450 diameter (mm)	24	24	24
525 diameter (mm)	36	46	48
600 diameter (mm)	48	48	48
>600 diameter and box culverts (mm)	60	60	60
Lined channels	1	6	12
Unlined channels	1	6	12
Maintained watercourses	4	9	12
Intakes / headwalls	1	5	12
Vleis and wetlands	6	10	12
Ponds	6	10	12

F.2.3.3 Corrective maintenance

Estimating the budget for corrective maintenance is difficult as it will be affected by the age of the system and the standards and levels of service to which the local authority aspires. The City of Cape Town spends approximately 10% of its annual maintenance budget on "repairs" (Austin, 2010). This is a rough guide and is based on a sub optimal (low) routine maintenance operation related to budgetary constraints. When the system is

optimally maintained (high) this may be reduced to 1% (estimate) of the annual maintenance budget.

F.2.3.4 Costs

The following costs for inspections and routine maintenance, Table F.2.5 – F.2.6, have been sourced from recent tenders, and budgeting documents compiled by the City of Cape Town's stormwater department. Where applicable the rates have been adjusted to 2010 Rand values.

Table F.2.5: Inspection rates for conventional systems

Asset	Inspection costs	
	Units	Rate (R)
Catch pits	Inspection	130
Conduits/Pipes	m	20-25
Lined channels	Inspection	130
Unlined channels	Inspection	130
Maintained watercourses	Inspection	160
Intakes / headwalls	Inspection	130
Vleis and wetlands	Inspection	210
Ponds	Inspection	180

F.2.3.5 Expected useful lives

There are no generally agreed upon 'expected useful lives' (EUL) for different components of a conventional stormwater system. Few municipal asset management plans will define the EUL, and where they do, the results vary dramatically or are questionable. This is especially evident in South Africa where available Municipal Asset Management Plans will estimate the EUL of a concrete pipe to be 40 years. International literature is also surprisingly thin on EUL of conventional systems. For this reason only one set of EUL is quoted here. These are from a recent study in South Australia by Tonkin Engineering Science. The study looked at the current Asset Management strategies. Each sample represents a local authority which contributed. The results relating to stormwater are presented in Table F.2.7. It is worth noting that where assets are not actively managed,

their EUL may deteriorate far sooner than expected (Narayanan & Pitt, 2005).

Table F.2.6: Inspection rates for conventional systems

Asset	Cleaning Costs	
	Units	Rate (R)
Connections	No.	63
Catch pits	No.	60
≤300 diameter (mm)	m	55
375 diameter (mm)	m	60
450 diameter (mm)	m	60
525 diameter (mm)	m	80
600 diameter (mm)	m	80
>600 diameter and box culverts (mm)	m	150
Box Culvert	m	350
Lined channels	m	37
Unlined channels	m	47
Maintained watercourses	m	280
Intakes / headwalls	No.	200
Vleis and wetlands	Ha	5,800
Ponds	m ²	1.3

Table F.2.7: EUL of Stormwater network components (Ellis & Callaghan, 2009)

Asset	councils	Min.	Max.	Median
RCP	8	50	100	100
FRC Pipe	4	80	100	100
U PVC	5	20	100	80
Box Culvert	6	50	100	75
Side Entry Pit	4	50	80	55
Junction Box	4	50	80	55
Headwall	5	50	80	50
Lined Channel	4	50	100	80
Unlined Channel	4	10	100	100

F.2.3.6 Further reading

Debo, T & Reese, AJ, 2003, *Municipal Stormwater Management*, Lewis Publishers, Boca Raton

Drainage Manual. (2007). Pretoria, South Africa: The South African National Roads Agency.

DoCGTA. (2010). *An Industry Guide To Infrastructure Guide To Service Levels And Unit Costs*. Department of Cooperative Governance and Traditional Affairs

Ellis, R., & Callaghan, P. (2009). *Infrastructure Asset Useful Lives - SA Councils Current Practises*. Tonkin Engineering Science.

Woods-Ballard, B, Kellagher, R, Martin, P, Jefferies, C, Bray, R & Shaffer, P, 2007, *The SUDS Manual*, CIRIA 697, London

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F.3 Rainwater harvesting

Rainwater harvesting is the collection, storage and reuse of stormwater runoff.

F.3.1 Capital costs

The capital costs are comprised of the storage unit, the additional piping and guttering required to convey the water storage unit. Additionally a 'first flush filter' is recommended to prevent the storage unit becoming filled with sediments and debris. Where required a booster pump may be added, however this is for convenience and are not required for the stormwater management aspects of this system.

F.3.2 Inspections

The system should be inspected regularly to ensure that the first flush diverter is emptied. This will protect the rest of system from sediments and debris. The storage unit should be checked to ensure sediments have not built up. These tasks can be undertaken quickly and simultaneously. Table F.3.1 displays inspection frequencies for rainwater harvesting systems.

Table F.3.1: Inspection frequencies (months)

Task	Source	Low	Med.	High
Inspection	WSUD Practise Note 4	6	4.5	3

F.3.3 Routine maintenance

In order to protect the system from a build-up of sediments the gutters upstream need to be cleaned, as well as the First Flush device. The roof catchment area should also be maintained and kept free of a build-up of pollutants. Table F.3.2 displays routine maintenance frequencies for rainwater harvesting systems.

Table F.3.2: Routine maintenance frequencies (months)

Task	Source	Low	Med.	High
Gutter	Estimate	12	12	6
First Flush Device	WSUD Practise Note 4	6	4.5	1
Roof Cleaning	Factors such as the type of roof, height above ground, use of water need to be considered.			

F.3.4 Irregular & corrective maintenance

The system is fairly robust, but sediment will build up, albeit slowly if the rest of the system is maintained properly. Where maintenance is poor the rate at which sediment will be needed to be removed will increase for the system to function properly. Table F.3.3 displays irregular maintenance frequencies for rainwater harvesting systems.

Table F.3.3: Irregular maintenance frequencies (years)

Task	Source	Low	Med.	High
Sediment Removal	WSUD Practise Note 4	10		
	Estimate		5	2

F.3.5 Expected useful life (EUL)

The EUL of the system is determined by the EUL of the rainwater tank. Therefore with proper maintenance and no unforeseen damage the system should last beyond the EUL's shown below. Table F.3.4 displays the EUL for rainwater harvesting systems.

Table F.3.4: Expected useful life

Subject	MUSIC	Narayanan
Design life (years)	25	>20

F.3.6 Typical unit rates

The costs of constructing the system are based upon those of a 'yard tank' connected to the gutters on a house (DoCGTA, 2010), with the addition of a first flush filter. While it may not be necessary to raise the rain water harvesting tank, there are a number of reasons for doing so, including the ability to pipe the stored water using gravity, negating the need for a pumping system. Table F.3.5 displays typical construction rates for rainwater harvesting systems.

Table F.3.5: Typical construction rates

Description	Units	Rate
Supply and install 5000 litre "Tank"/Water Butt (P&G's = 15%)	No	14,284
Supply and install 5000 litre "Tank"/Water Butt (no Stand) (P&G's = 15%)	No	7,672
Supply & Install First Flush Device	No	1,800

Maintenance costs reflect estimates of the costs were a contractor to be responsible for the maintenance of a system. Rainwater harvesting can easily be maintained by the home owner. Table F.3.6 displays typical rates for maintenance for rainwater harvesting systems.

Table F.3.6: Typical rates for maintenance

Description	Unit	Rate (R)
Inspections	Visit	160
First flush - cleaning requires inspection	Visit	150
Gutter cleaning	m	Included in roof clean
Roof cleaning	m ²	0.75 (excl. water used)
Sediment removal	m ³	71

F.4 Green roofs

Green roofs are roofs designed to carry a vegetated layer that lies on the surface of roof. It may be composed of vegetation - from grass species to small shrubs.

F.4.1 Capital costs

The capital costs for a green roof vary widely depending on whether it is a modular or direct application, whether it includes or excludes insulation, and the height above the ground at which it is to be constructed. All these factors and their impact on the maintenance of the system need to be taken into account.

F.4.2 Inspections

Green roofs are effectively elevated bio-retention areas, and although the Lampe *et al* (2005) report does not specify an inspection schedule for them a reasonable approximation is that of small scale/bio retention SUDS. Additionally after big storm events it is advisable to ensure the system drains within the required time by checking the inspection chambers. Table F.4.1 displays inspection frequencies for green roofs.

Table F.4.1: Inspection frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	0	36	12
Lampe <i>et al</i> USA	36	6	1

F.4.3 Routine maintenance

"The different vegetative roofing system manufacturers have different maintenance recommendations, so it depends on the system you're installing...it depends on intensive versus extensive. It depends on built in place versus modular" (Matt, 2009). Routine maintenance is primarily about vegetation management, and the replacement of soil that is lost due to "erosion", be it water or wind erosion. While the system is being established it may also include the replacement of

plants that do not survive. Table F.4.2 displays routine maintenance frequencies for green roofs.

Table F.4.2: Routine maintenance frequencies (months)

Task	Source	Low	Med.	High
Litter Management	Lampe <i>et al</i> UK	12	4	1
Management of Vegetation	Lampe <i>et al</i> UK	6	4	1
Vegetation	Lampe <i>et al</i> USA	36	6	1

F.4.4 Irregular & corrective maintenance

Corrective maintenance is generally concerned with the management of the roof's water proofing layers and management/unblocking of the drainage layer. Table F.4.3 displays irregular maintenance frequencies for green roofs.

Table F.4.3: Irregular Maintenance Frequencies (months)

Task	Low	Med.	High
Repair waterproof layer	Dependent on quality of construction, and site factors		
Replace soil	Site specific		

F.4.5 Expected useful life (EUL)

The expected life of a system is determined in the design phase. It is dependent on the type of system-modular, or direct application- and the type of vegetation. (Narayanan & Pitt, 2005) showed how three different green roofs had varying EUL's of between 10 and 40 years simply due to the design selected. Table F.4.4 displays the EUL for green roofs.

Table F.4.4: Expected Useful Life

Subject	Narayanan	Fisher <i>et al.</i> (
Design life	10-40 (based on design)	> 90 years

F.4.6 Typical unit rates

Maintenance costs, as with construction costs, will vary depending on the accessibility of the roof, the function of the roof, and the scale of the project. Households with easy accessibility could potentially be managed by the homeowner at no additional cost. Table F.4.5 displays typical construction rates for green roofs. Table F.4.6 displays typical maintenance rates for green roofs.

Table F.4.5: Typical construction rates

Description	Units	Rate (R)
Derbigum SP4 Waterproof layer	m ²	174
Aggregate	m ³	215
Geo Textile (Filter Fabric - Bidim)	m ²	21
Inspection Eyes	no	102
Plant Layer/vegetation	m ²	46
Top soil Supplied by contractor, Spread in 100-200mm thick layers	m ³	161
Plants Supplied & planted	m ²	46
Supply and add mulch to shrub areas (20mm)	m ²	62
Grassing per m ²	m ²	20-50
Crane Hire - all terrain hydraulic crane, 18 ton	day	4584
Green Roof Estimate - Height not accounted for (HNAF)	m ²	444
Green Roof Estimate - (GRPP) - Direct application (HNAF)	m ²	400
Green Roof Estimate - GRPP - Modular application (HNAF)	m ²	480

Table F.4.6: Typical maintenance rates

Description	Unit	Rate (R)
Inspections	Visit	210
Litter & vegetation management	Visit & m ²	2.00-2.40
Soil replacement	m ³	161
Repair of water proof layer	Dependent on damage	

F.5 Infiltration trenches and soakaways

Infiltration trenches and soakaways essentially operate in the same manner. The purpose of these SUDS is to collect, store and infiltrate runoff. They are commonly constructed as trenches filled with void forming media - stone. Filter trenches are not the same as infiltration trenches, although in design they are similar. Filter trenches are designed to convey runoff and therefore often have perforated pipes running their length, infiltration trenches generally do not.

F.5.1 Capital costs

The design is relatively standard, while the "void former" – be it aggregate or geo-cellular units – may impact on the cost and efficiency of the design. Sub surface (generally soakaways) needs to include an overflow. Filter trench costs may be estimated, although it is necessary to include the perforated pipe.

F.5.2 Inspections

Inspections should be undertaken to ensure the system is draining within the design period. This is accomplished through regular inspections as well as inspections after large storm events. Once it is no longer draining effectively corrective maintenance should be undertaken. Table F.5.1 displays the inspection frequencies for infiltration trenches and soakaways.

Table F.5.1: Inspection frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	36	12	3
Lampe <i>et al</i> USA	>36	12	1

F.5.3 Routine maintenance

As these systems are sub surface, it is often difficult to access them for maintenance. Routine maintenance therefore considers the immediate surroundings and comprises litter and vegetation

management. Vegetation management is important to prevent the geo-synthetic layer being breached which could lead to the clogging of the system. Additionally some form of pre-treatment is advisable – swale/filter strip – as it will decrease the sediment loads, decreasing the sediment entering the SUDS option. Table F.5.2 displays routine maintenance frequencies for infiltration trenches and soakaways.

Table F.5.2: Routine Maintenance Frequencies (months)

Task	Source	Low	Med.	High
Litter & vegetation & Surface management	Lampe <i>et al</i> UK	36	6	2
Litter & Vegetation & surface Management	Lampe <i>et al</i> US	36	6-12	1

F.5.4 Irregular & corrective maintenance

Corrective maintenance is generally undertaken when the system is no longer disposing of the runoff in the required time. This can be done in one of two ways. Either the entire system is replaced, or the top layer (gravel and geo-synthetic) are removed and replaced. This assumes that the rest of the system is not clogged – dependent on design. The WERF, (2005) UK maintenance report states that it does not expect climate to affect the maintenance of this SUD. As is evident from the EUL's below the UK estimates seem to be overly hopeful. Table F.5.3 displays the irregular maintenance frequencies for infiltration trenches and soakaways.

Table F.5.3: Irregular Maintenance Frequencies (months)

Task	Source	Low	Med.	High
Routine scarifying of top layer	Lampe <i>et al</i> UK	480	240	120
Overhaul system	Lampe <i>et al</i> US	60	48	18

F.5.5 Expected useful life (EUL)

A range of EUL's are possible. This is mainly due to the poor reputation of the system, a direct result of poor maintenance internationally. MUSIC considers a EUL (Professional opinion) of 50 years. While this may be possible, case studies with this EUL are rare, additionally poor maintenance leads these systems to premature failure. Table F.5.4 displays the EUL for infiltration trenches and soakaways.

Table F.5.4: Expected useful life

	EPA in Jefferies	MUSIC	FHWA
Design Life	5-15	20-50	10

F.5.6 Typical unit rates

Table F.5.5 displays typical construction rates for green roofs. Table F.5.6 displays typical maintenance rates for infiltration trenches and soakaways.

Table F.5.5: Typical construction rates

Description	Units	Rate (R)
Clear and Remove Topsoil	m ²	7
Cut to Spoil	m ³	82
Surface bed preparation	m ²	34
Geo Textile (Filter Fabric - Bidim)	m ²	21
"Chamber"	-	-
Stone Fill (Different Diameters: see permeable paving)	m ³	266
Building sand	m ³	343
Supply and Lay 160mm slotted drainage pipe	m	64
"Sub Surface"/Soakaways	-	-
Topsoiling of verge areas	m ²	6
Grassing per m2	m ²	20 - 50
Standard surface Infiltration Trench (30% Voids ratio)	m ³	572

Table F.5.6: Typical maintenance rates

Description	Unit	Rate (R)
Inspections	Visit	180
Litter & Vegetation Management	/visit.m ²	2
Overhaul top layer (to geosynthetic)	m ³	42
Complete overhaul of system is equivalent to construction cost		

F.6 Bio-retention / rain gardens

Bio retention cells and 'rain gardens' are engineered gardens that detain, treat and infiltrate runoff. They may include an under drain connecting into the municipal sewer.

F.6.1 Capital costs

The capital costs are comprised of excavation, layer works, and landscaping. Additionally when an under drain is included the costs of connecting to the municipal sewer must be considered

F.6.2 Inspections

As with all SUDS of this nature, regular inspections are necessary, both to ensure that litter, sedimentation and excessive vegetation does not impact on the systems functioning, and to ensure that the system is functioning properly during and after large storm events. Table F.6.1 displays inspection frequencies for bio-retention areas.

Table F.6.1: Inspection Frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	24	6	1
Lampe <i>et al</i> USA	36	6	1

F.6.3 Routine maintenance

Routine maintenance is considered to be equivalent to any other small SUD, and comprises litter and vegetation management. The position in the treatment train is important, and where possible, pre-treatment should be included to remove sediment. Table F.6.2 displays routine maintenance frequencies for bio-retention systems.

Table F.6.2: Routine maintenance frequencies (months)

Task	Source	Low	Med.	High
Litter Management	Lampe <i>et al</i> UK	12	4	1
Vegetation Management	Lampe <i>et al</i> UK	6	4	1
Vegetation and Litter Management	Lampe <i>et al</i> USA	36	6-12	1

F.6.4 Irregular & corrective maintenance

Corrective maintenance, which comprises management of accumulated sediment, is dependent on upstream sediment management. Additionally if the Bio retention unit does not drain within the design period (24-36 hrs) there may be a need to either cultivate/scarify the top soil layers or overhaul the system. Table F.6.3 displays irregular maintenance frequencies for bio-retention systems.

Table F.6.3: Irregular maintenance frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> USA	1200	78	18

F.6.5 Expected useful life (EUL)

As with other SUDS systems there is extensive variation with respect to the EUL of the system. It is important to consider the soil conditions, catchment areas, and treatment train design and maintenance schedule. If possible the bio retention cell should be preceded by a small swale, filter strip, or sediment bay. Table F.6.4 displays the EUL for bio-retention areas.

Table F.6.4: Expected Useful Life

Subject	MUSIC	Narayanan
Design life	25-50 years	20 used in model

F.6.6 Typical Unit Rates

Table F.6.5 displays typical construction rates for green roofs. Table F.6.6 displays typical maintenance rates for bio-retention areas.

Table F.6.5: Typical construction rates

Description	Units	Rate (R)
Clear and Remove Topsoil	m ²	7
Cut to Spoil	m ³	82
300*300 stone drain covered in Geofabric (110mm drainex pipe)	m	159
Backfilling with selected material	m ³	123
Top soil Supplied by contractor, Spread in 100-200mm thick layers	m ³	161
Plants Supplied & planted	m ²	46
Supply and add mulch to shrub areas (20mm)	m ²	62
Surrounding Areas:		
Top soiling of verge areas	m ²	6
Grassing per m2	m ²	20 - 50
Unit rate for Bio retention Garden	m ²	407
Irrigation per m2	m ²	19

Table F.6.6: Typical maintenance rates

Task	Unit	Rate (R)
Inspections	Visit	210
Litter & Vegetation Management (Quarterly)	/visit. m ²	2.00- 2.40
Sediment Removal	m ³	71

F.7 Permeable pavements

Permeable pavements allow water to percolate through them. Often the runoff is detained in a storage unit from where it either infiltrates or is released at a reduced flow rate.

F.7.1 Capital costs

Capital costs are dependent on the specific design, whether it is a full infiltration, partial infiltration or fully contained system. For partial or full infiltration systems it is important that the outlet be sized correctly. Additionally the connection of the outlet into the municipal sewer will result in an additional cost.

F.7.2 Inspections

Permeable pavements require inspections to ensure that the system is being optimally managed. Further inspections should be carried out after storm events to ensure that it is still operating within design limits. Table F.7.1 displays inspection frequencies for permeable pavements.

Table F.7.1: Inspection frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	12	6	1
Lampe <i>et al</i> USA	36	6	1

F.7.3 Routine maintenance

The routine management of litter, solid waste and vegetation to prevent the system clogging is required. Sweeping has been shown to dramatically increase the functioning of the system. Table F.7.2 displays routine maintenance frequencies for permeable pavements.

Table F.7.2: Routine maintenance frequencies (months)

Task	Source	Low	Med.	High
Litter management	Lampe <i>et al</i> UK	60	12	2
Sweeping	Lampe <i>et al</i> UK	12	6	4
Sweeping and Litter Management	Lampe <i>et al</i> US	36	6-12	1

F.7.4 Irregular & corrective maintenance

Corrective maintenance is as for any CBP pavement and entails fixing any local pavement failures. Due to the wide variation resulting from different uses and quality of construction it is difficult to estimate frequencies. Another task is the removal of sediment collected in the pavement. Sediment should partially be managed through routine sweeping. Once clogged the system may need to be cleaned using a vacuum cleaner –not available in RSA- or partially overhauled. Current evidence from Australia indicates the majority of sediments are collected in the top 25mm of the paving layer works; hence this could be removed and replaced. Table F.7.3 displays irregular maintenance frequencies for permeable pavements.

Table F.7.3: Irregular Maintenance (months)

Task	Source	Low	Med.	High
Sediment Removal	Lampe <i>et al</i> US	Highly variable 15 yrs (0-20)		

F.7.5 Expected Useful Life

The design lives listed below relate to the system clogging. Evidence from Australia indicates only the top 25mm of the system would need to be overhauled, for the system to function properly again. Table F.7.4 displays the EUL for permeable pavements.

Table F.7.4: Expected Useful Life

	Jefferies, C	Shackel
Design Life	15-20 before clogging	>10years based on current research at 10 years

F.7.6 Typical Unit Rates

Table F.7.5 displays typical construction rates for green roofs. Table F.7.6 displays typical maintenance rates for permeable pavements.

Table F.7.6: Typical Maintenance Rates

Description	Unit	Rate (R)
Inspections	Visit	180
Sweeping	/visit.m2	0.05-0.10
Structural repairs	m2	190
Overhaul of top 25mm	m2	40

Table F.7.5: Typical Construction Rates

Description	Units	Rate (R)
Cut to Fill	m ³	39
Cut to Spoil	m ³	79
Overhaul to dumpsite	m ³ /km	0.10 - 8.00
Layer Works:		
Supply, install and compact 250 mm thick, 10 - 63 mm course aggregate, no fine	m ³	244
Supply, install and compact 100 mm thick, 5 - 20 mm course aggregate, no fines.	m ³	287
Supply, install and compact 50 mm thick, 5 mm course aggregates, no fines.	m ³	275
Supply and install 50 kN/m Rock Grid, PC Range 2.6 mm thick Geosynthetic	m ²	49
Supply and lay 160mm diameter Geopipe - Subsurface drainage	M	64
Aquaflow permeable paving blocks 200X110X80mm, 50 MPa as per INCA - colour: Infiltration rate: 2.5 l /sec/m ²	m ²	155
Connection for sub-surface drainage into existing stormwater network	No	51
Kerbing:		
Kerbing and Channelling straight	m	156
Kerbing and Channelling curves	m	181
Permeable Paving unit rate (P&G's = 15%)	m ²	450

F.8 Grass swale

A swale is a shallow vegetated grass channel that is designed to filter runoff as it conveys the runoff. The design can be modified to aid in infiltration by adding check dams and through additional layer works (Enhanced Dry swale). O&M is as for a grass swale although inspections would include checking the layer works are still draining properly, and the check dams have not been eroded.

Swales can additionally be designed to ensure biological treatment i.e. wet swales which do not drain entirely, and through vegetation selection. Operations and maintenance of the associated with pocket wetlands and retention ponds may be reduced through the effective use of swales to remove sediments.

F.8.1 Capital costs

A grass swale is relatively simple to construct as they are effectively trapezoidal grassed channels. Check dams may also be included and can be constructed from stone, or small 'gabion' walls.

F.8.2 Inspections

The swale should be inspected to prevent damage due to erosion and sediment build up. Swales are commonly used to remove sediment before it enters wet or underground SUDS, and thus sediment build up is an important aspect of the inspection. Table F.8.1 displays inspection frequencies for grass swale.

Table F.8.1: Inspection frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	24	6	1
Lampe <i>et al</i> USA	36	6	1

F.8.3 Routine maintenance

Routine maintenance comprises of removing litter and cutting grass. Some sources suggest leaving the grass cuttings, however during the rainy season this is inadvisable as it will become a pollutant and

block downstream SUDS. Table F.8.2 displays routine maintenance frequencies for grass swale.

Table F.8.2: Routine Maintenance (months)

Task	Source	Low	Med.	High
Litter Management	Lampe <i>et al</i> UK	12	4	1
Grass Cutting	Lampe <i>et al</i> UK	6	4	1
Grass Cutting, weeding and Litter Management	Lampe <i>et al</i> USA	36	6-12	1

F.8.4 Irregular & corrective maintenance

Corrective maintenance is limited to sediment removal when sediment begins impacting on the hydraulic capacity of the swale i.e. 10% of height/equivalent of over board or according to design specifications. Erosion management is also vital and any signs of erosion should be dealt with to prevent compounding the damage in future storm events. Table F.8.3 displays irregular maintenance frequencies for grass swale.

Table F.8.3: Irregular Maintenance Frequencies (months)

Task	Source	Low	Med.	High
Erosion and Sediment Management	Lampe <i>et al</i> USA	1200	78	18

F.8.5 Expected useful life (EUL)

A well maintained swale has the potential to last indefinitely. Literature however indicates swales may have service lives ranging from 10-50 years. Enhanced swales especially may require extensive layer works to reinstate. Table F.8.4 displays the EUL for grass swales.

Table F.8.4: Expected Useful Life

	Jefferies, C	MUSIC	FHWA
Design Life	10 years	25-50 years	20-50 years

F.8.6 Typical unit rates

Table F.8.5 displays typical construction rates for green roofs. Table F.8.6 displays typical maintenance rates for grass swale.

Table F.8.5: Typical construction rates

Description	Units	Rate (R)
Clear and Grub	m ²	4
Strip and Remove Topsoil	m ³	27
Cut to Spoil	m ³	82
Trimming Side Drains to Profile, Compact	m	27
Levelling Verges	m	19
Grassing	m ²	20-50
Swale per m (P&G's = 15%)	m	305
Construct Scour Protection (steep sections)	Ea	440

Table F.8.6: Typical Maintenance Rates

Description	Unit	Cost (R)
Inspections	Visit	160
Litter & Vegetation Management	visit.m ²	1.50-2.40
Erosion	m ²	35
Sediment Management	m ³	71

F.9 Buffer & filter strips

Buffer & Filter strips are effectively vegetated grass slopes that are designed to filter runoff. The design can be modified to aid in infiltration (use of a berm) or aid biological treatment.

F.9.1 Capital costs

The construction of Buffer and Filter strips require the grading and cultivation of open land.

F.9.2 Inspections

Buffer & Filter strips should be inspected to prevent damage due to erosion and sediment build up. Table F.9.1 displays inspection frequencies for buffer and filter strips.

Table F.9.1: Inspection frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	24	6	1
Lampe <i>et al</i> USA	36	6	1

F.9.3 Routine maintenance

Routine maintenance comprises of litter and vegetation management. Table F.9.2 displays routine maintenance frequencies for buffers and filter strips.

Table F.9.2: Routine maintenance frequencies (months)

Task	Source	Low	Med.	High
Litter Management	Lampe <i>et al</i> UK	12	4	1
Grass Cutting	Lampe <i>et al</i> UK	6	4	1
Grass Cutting, weeding and Litter Management	Lampe <i>et al</i> USA	36	6-12	1

F.9.4 Irregular & corrective maintenance

Corrective maintenance is limited to sediment removal (especially when a berm is used) and erosion management. It is ideal if the SUD is designed with a flow spreader i.e. Pea stone filter to minimise the chances of concentrated flow. Literature suggests a similar maintenance schedule as for swales. Table F.9.3 displays irregular maintenance frequencies for buffers and filter strips.

Table F.9.3: Irregular maintenance frequencies (months)

Task	Source	Low	Med.	High
Sediment removal and erosion	Lampe <i>et al</i> USA	1200	78	18

F.9.5 Expected useful life (EUL)

A Buffer or filter strip has the potential to last indefinitely. Literature indicates Buffers & Filter strips may have service lives ranging from 20-50 years. Table F.9.4 displays the EUL for buffers and filter strips.

Table F.9.4: Expected Useful Life

	Jefferies, C	MUSIC	Narayanan
Design Life	20-50 years	25-50 years	20 used in WLC

F.9.6 Typical unit rates

The construction rates given below based on the DoCGTA (2010), MIG Guidelines. However if extensive cut and/or fill is required these will be inappropriate. Table F.9.5 displays typical construction rates for green roofs. Table F.9.6 displays typical maintenance rates for buffers and filter strips.

Table F9.5: Typical construction rates

Description	Units	Rate (R)
Earthworks per m2	m ²	4.50
Grassing per m2	m ²	20
Buffer/Filter Strip unit rate (P&G's = 15%)	%	28
Irrigation per m2	m ²	20

Table F9.6: Typical maintenance rates

Description	Unit	Cost
Inspections	Visit	180
Litter & Vegetation Management (monthly)	/visit. m ²	1.50- 2.40
Erosion	m ²	35
Sediment Management	m ³	71

F.10 Wetlands & retention ponds

Wetlands and Retention ponds are controls which maintain a permanent pool of water. The major difference from a design point of view is that a retention pond has 25 to 50 per cent of the pond surface area covered with vegetation, whereas a wetland has 75 to 100 per cent coverage (Jefferies, 2010).

F.10.1 Capital costs

Wetlands and retention ponds require extensive landscaping works. Additionally the outlet would need to be design to ensure that the system retains runoff for the design period. There are also a number of variations, such as the submerged gravel wetlands which complicate the costing of these SUDS.

F.10.2 Inspections

Inspections are based on those of a wet retention pond. Inspections include checking and monitoring for mosquitoes (vector control) etc. Table F.10.1 displays inspection frequencies for wetlands and retention ponds.

Table F.10.1: Inspection frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	>12	<4	<1
Lampe <i>et al</i> USA	>36	36	12 + Events

F.10.3 Routine maintenance

Routine maintenance includes the removal of litter, mowing of grass banks and general management of vegetation. Routine maintenance should include the checking and cleaning of inlets and outlets. Table F.10.2 displays routine maintenance frequencies for wetlands and retention systems.

Table F.10.2: Routine maintenance frequencies (months)

Task	Source	Low	Med.	High
Litter and general vegetation Management	Lampe <i>et al</i> US	36	6 - 12	1

F.10.4 Irregular & corrective maintenance

Irregular maintenance includes tasks such as vector control, algae removal and management. These tasks are climate and site specific and difficult to predict. Sediment removal requirements will be dependent on the treatment train design and general maintenance of the system. Table F.10.3 displays irregular maintenance frequencies for wetlands and retention systems.

Table F.10.3: Irregular maintenance frequencies (months)

Task	Source	Low	Med.	High
Sediment Removal	Lampe <i>et al</i> UK	600	300	120
Sediment Removal Main Pool	Lampe <i>et al</i> US	480	360	240
Sediment Removal Fore bay	Lampe <i>et al</i> US	240	60-120	12-24

F.10.5 Expected useful life (EUL)

The EUL of wetlands and retention ponds will be dependent on the system design. Expert opinion suggests that they should last for 50 years, although poor design and maintenance will result in premature failure. Table F.10.4 displays the EUL for wetlands and retention ponds.

Table F10.4: Expected useful life

	USEPA (Jefferies, 2005)	MUSIC	FHWA (Jefferies, 2005)
Design Life	>20	30-50	20-50

F.10.6 Typical unit rates

Currently no estimates for the construction of wetlands are available. Table F.10.5 displays typical maintenance rates for wetlands and retention ponds.

Table F.10.5: Typical maintenance rates

Description	Unit	Rate (R)
Inspections	Visit	210
Vegetation Management (large)	/visit.m ²	0.60
Vegetation Management (pocket wetlands)	/visit.m ²	2.00-2.40
Sediment Removal (Standard wetland)	m ³	Site dependant >160
Sediment Removal(Submerged Gravel)	Capital Cost	

F.11 Detention ponds

Detention ponds / detention basins are ponds designed to temporarily detain runoff. They drain within a specified period of time, usually 24-48 hours. Retention ponds are considered along with wetlands in this guideline, the difference between wetlands and retention ponds is discussed in the following section.

F.11.1 Capital costs

Detention ponds may be constructed using a range of techniques, from simple excavation, to the use of retaining walls etc. Additionally designs may include sediment fore bays to reduce sediment entering the rest of the detention pond while making routine and irregular maintenance a lot simpler and cheaper. It is also important that the type of outlet is carefully considered. It also important to consider how major storm events will be managed, and include the cost of the spillways etc.

F.11.2 Inspections

The inspection should consider the general state of the detention pond, including the impact of sedimentation, vegetation growth, the state of the in and outlets etc. Table F.11.1 displays inspection frequencies for detention ponds.

Table F.11.1: Inspection frequencies (months)

Source	Low	Med.	High
Lampe <i>et al</i> UK	>12	<4	<1
Lampe <i>et al</i> USA	>36	36	12 + large storm events

F.11.3 Routine maintenance

Routine maintenance includes the removal of litter, mowing of grass banks and general management of vegetation. Additionally routine maintenance should ensure the sediment fore bay/basin, inlets and outlets are operational. Table F.11.2 displays

routine maintenance frequencies for detention ponds.

Table F.11.2: Routine maintenance frequencies (months)

Task	Source	Low	Med.	High
Litter & Vegetation management	Lampe <i>et al</i> US	36	6-12	1
Litter removal	Lampe <i>et al</i> UK	12	6	1
Grass Cutting	Lampe <i>et al</i> UK	36	3	1
Clean sediment in fore bay	Lampe <i>et al</i> UK	12	12	12

F.11.4 Irregular & corrective maintenance

Irregular maintenance includes tasks such as vector control (ensuring the detention pond empties within the design period), algae removal (sediment bay) and management. These tasks are climate and site specific and difficult to predict. Sediment removal requirements will be dependent on the treatment train design and general maintenance of the system. Table F.11.3 displays irregular maintenance frequencies for detention ponds.

Table F.11.3: Irregular maintenance frequencies (months)

Task	Source	Low	Med.	High
Sediment Removal	Lampe <i>et al</i> USA	240	96	36
Sediment removal & Dewatering	Lampe <i>et al</i> UK	600	300	120

F.11.5 Expected useful life (EUL)

The EUL of a stormwater management pond is largely dependent on the design of the whole system. If the stormwater pond is not protected from sediment by upstream controls it will

inevitably have a much reduced EUL. Table F.11.4 displays the EUL for detention ponds.

Table F.11.4: Expected Useful Life

	Jefferies, C	MUSIC	FHWA (Jefferies, 2005)
Design life	Dependent on maint.	50 years	20-50 years

Table F.11.6: Typical maintenance rates

Description	Unit	Rate (R)
Inspections	Visit	180
Litter & Vegetation Management	/visit.m ²	0.60 - 2.20
Sediment Removal	m ³	157

F.11.6 Typical Unit Rates

Table F.11.5 displays typical construction rates for green roofs. Table F.11.6 displays typical maintenance rates for detention ponds.

Table F.11.5: Typical construction rates

Description	Units	Rate (R)
Earthworks:		
Cut to Fill	m ³	39
Excavate Detention ponds 1-2m deep	m ³	18
Overhaul	m ³ /km	0.10 – 8.00
Foundation trench excavation and backfilling:		
Excavate material	m ³	103
Surface bed preparation for bedding of gabions	m ²	70
Gabions (2.0 x 1.0 x 1.0) PVC coated gabion boxes 2,7mm diameter galvanised wire, to SANS 1580, including rock infill	m ³	1250
Geo Textile (Filter Fabric - Bidim)	m ²	21
Reno Mattresses (3.0 x 1.0 x 0.3 PVC boxes)	m ³	1587
Gabions, Reno Mattress, Stone Pitching	m ²	333
Inlets:		
Pond Inlet/Outlet	No	23550
Attenuation pond outlet (2006 includes P&G, VAT)	No	550000
Grassing:		
Grassing per m ²	m ²	20